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(54) Title: EXTRUDED POLYOLEFIN RESIN FOAM

(57) Abstract: The present invention provides thick extruded foam which is extruded polyolefin resin foam having open cells, used for cushion material and packaging material and the like, which exhibits uniform physical product properties, high expansion ratio, and uniform cell diameter. The extruded open cell foam of the present invention is an extruded foam exhibiting an open cell foaming ratio of 50% or greater, the base resin whereof is principally composed of a mixed polymer consisting of 4.5 to 75 parts by weight of component A consisting of an ethylene ionomer resin, 0.5 to 30 parts by weight of component B consisting of a polyolefin resin having a melting point exceeding 120°C, and 20 to 95 parts by weight of component C consisting of one or two or more polymers selected from a group of ethylene-propylene rubbers, styrene elastomers, and polyethylene resins having melting points of 120°C or lower (where component A + component B + component C = 100 parts by weight). Various kinds of additives such as anti-shrinking agents can be mixed in this extruded foam.

## DESCRIPTION

### EXTRUDED POLYOLEFIN RESIN FOAM

## TECHNICAL FIELD

5           This invention relates to extruded polyolefin resin foam used in cushion material, packaging material, sound absorbing material, water absorbing material, anti-vibration material, and various kinds of industrial filters, etc.

10

## BACKGROUND ART

          The open cell foams made of synthetic resins known to the prior art include urethane foams, foam rubber, and ethylene-vinyl acetate copolymer foams, etc. These foams, because they are flexible and exhibit good processability, 15 have been used in such applications as cleaning sponges, shock absorbing materials, cushion materials, sound absorbing materials, and various industrial filters. Nevertheless, applications for these open cell extruded 20 foams have been limited due to their inferiority in terms of chemical resistance (acid resistance, alkali resistance, etc.) and weatherability. Furthermore, urethane foams and foam rubber are very difficult to recycle back to raw materials, while ethylene-vinyl acetate copolymer foams are

problematic because of their large amount of foul odor during manufacture.

Polyolefin resins, on the other hand, exhibit very outstanding chemical resistance and weatherability, as well as outstanding recyclability. Accordingly, the problems noted above can be overcome if the open cell extruded foam is made of a polyolefin resin.

That being so, attempts have been made before to develop open cell polyolefin resin foams. Art is known, for example, for subjecting a closed cell polyolefin resin foam to pinhole processing to form open cell foam. However, open cell polyolefin resin foams obtained by simply subjecting closed cell foams made from polyethylene resin or polypropylene resin base material to pinhole processing exhibit high permanent compression set, and do not have sufficient shock-absorbing properties to stand up under prolonged use.

Other methods have also been reported, such as that described in Japanese Patent Publication No. S60-55290/1985 which uses a mixture of low-density polyethylene and high-density polyethylene, and that described in Japanese Patent Application Laid-Open No. 2000-7817 which uses a mixture of low-fluidity and high-fluidity low-density polyethylenes as the base resin for obtaining an open cell extruded foam.

With those methods, however, foam of sufficient thickness, width, and expansion ratio are not obtained, nor do such foams exhibit adequate practical usability. Also known are open cell foams made of polyolefin resins and ionomer resins. In Japanese Patent Application Laid-Open No. H10-279724/1998, for example, a foam is disclosed wherein for 0 to 50 parts by weight of a polyolefin resin are used 100 to 50 parts by weight of a costly ionomer resin. However, when foam extrusion of an open cell foam of such mixture as noted above is performed, the extrusion pressure is high, wherefore heat generation at the die is severe, making it very difficult to obtain good open cell extruded foams exhibiting a high expansion ratio and high thickness. In addition, the molten resin setting temperature (hereinafter called the foaming temperature) must be regulated within a narrow range during extrusion foaming in order to obtain the open cell extruded foam, making stable manufacture difficult. Also, in Japanese Patent Application Laid-Open No. 59-196384/1994, a foam wherein for 100 parts by weight of a polyolefin resin, 60 to 150 parts by weight of an ionomer resin are used, but this is small rod-shaped foam having a cross-sectional area of 0.1 cm<sup>2</sup> or so which is used as core material in sealers used in window frames and the like, for example.



In Japanese Patent Application No. 2000-23179, an open cell extruded foam is described wherein a mixture of two or three or more polyolefin resins having different melting points is used as the base resin. More specifically, in 5 this patent application, an open cell extruded foam is described, the main component whereof is a mixed polymer configured by a component consisting of a polyolefin resin, and a component consisting either of one or two or more polymers selected from a group made up of ethylene- $\alpha$ , or  $\beta$  10 unsaturated carboxylic acid copolymers (but excluding ionomers), olefin elastomers, styrene elastomers, and ethylene-vinyl acetate copolymers, or of such mixed polymer to which a heat reversible crosslinked polymer has been added.

15 With the resin mixture described above, the range of suitable foaming temperatures wherewith the open cell foam can be stably obtained is narrow, and, if the foaming temperature is higher than the suitable foaming temperatures, the foam contracts, making it difficult to 20 obtain foam having the desired expansion ratio and thickness, whereas, if the foaming temperature is lower than the suitable foaming temperatures, the closed cell foaming ratio rises and the desired open cell foam is not obtained. If an attempt is made to obtain an open cell

foam of high foaming expansion ratio, moreover, the cell wall thickness of the foam becomes thin, it becomes very difficult to retain the shape of the open cell foamed cell walls during extrusion foaming, and good foam is difficult to obtain.

Thus, in the prior art, it has been very difficult to stably manufacture foam exhibiting uniform physical product properties, and to stably manufacture polyolefin resin open cell extruded foam exhibiting high expansion ratio and high open cell foaming ratio, especially thick product exhibiting uniform physical properties.

With the foregoing in view, it is an object of the present invention to provide extruded open cell foam of uniform physical product properties, with a high expansion ratio, and uniform cell diameter, particularly such extruded open cell foam that is thick.

#### DISCLOSURE OF THE INVENTION

The present invention is an extruded polyolefin resin open cell foam having an open cell foaming ratio of 50% or higher. The base resin of the foam of the present invention has as its main component a mixed polymer consisting of 4.5 to 75 parts by weight of a component A consisting of an ethylene ionomer resin, 0.5 to 30 parts by

weight of a component B consisting of a polyolefin resin  
having a melting point exceeding 120°C, and 20 to 95 parts  
by weight of a component C consisting of one or two or more  
polymers selected from a group of ethylene-propylene  
5 rubbers, styrene elastomers, and polyethylene resins having  
melting points of 120°C or lower (where component A +  
component B + component C = 100 parts by weight).

The component B consisting of the polyolefin resin  
having a melting point exceeding 120°C should be one or two  
10 or more mixed resins selected from among polypropylene  
resin, linear low-density polyethylenes, and polyethylene  
resins having a density of 940 kg/m<sup>3</sup> or greater.

The polyethylene resin having a melting point of 120°C  
or lower in component C should be one or two or more mixed  
15 resins selected from among low-density polyethylenes,  
ethylene- $\alpha$ , or  $\beta$  unsaturated carboxylic acid copolymers  
(but excluding ionomers), and ethylene-vinyl acetate  
copolymers.

An anti-shrinking agent can be added to the base resin,  
20 whereupon the amount added should be 0.1 to 15 parts by  
weight for 100 parts by weight of the basic resin.

The extruded open cell foam of the present invention  
should have a density of 15 to 200 kg/m<sup>3</sup> and thickness of

0.5 to 200 mm, which can be configured either as sheet-form foam or plank-form foam. The shape is not limited to a flat shape, however, and rod-shaped foam can also be configured. The form of the rod shapes may be either one  
5 with a hollow cross-section or solid cross-section, with a density of 15 to 100 kg/m<sup>3</sup> and an area of cross-section (perpendicular to direction of extrusion) of 0.7 cm<sup>2</sup> or greater being preferred.

Based on the present invention, in an extruded open  
10 cell foam of broad width, or an extruded open cell foam of large thickness, having a high expansion ratio, good foam is realized with uniform cell diameter and little partial variation in mechanical properties. In the present invention, furthermore, by adding the base resin configured  
15 as described in the foregoing, particularly by adding a specific amount of the polyolefin resin having a melting point exceeding 120°C of component B, to the components A and C, benefits are realized in that the range of suitable foaming temperature for stably obtaining the extruded open  
20 cell foam broadens, manufacture of the extruded open cell foam is made easy, and product yield can be improved.

BEST MODE FOR CARRYING OUT THE INVENTION

The extruded polyolefin resin foam of the present invention is an extruded polyolefin resin open cell foam having an open cell foaming ratio of 50% or higher. The base resin for this extruded open cell foam has as its main component a mixed polymer consisting of 4.5 to 75 parts by weight of a component A consisting of an ethylene ionomer resin, 0.5 to 30 parts by weight of a component B consisting of a polyolefin resin having a melting point exceeding 120°C, and 20 to 95 parts by weight of a component C consisting of one or two or more polymers selected from a group of ethylene-propylene rubbers, styrene elastomers, and polyethylene resins having melting points of 120°C or lower (where component A + component B + component C = 100 parts by weight).

The mixed polymer that is the main component in the base resin configuring the extruded open cell foam of the present invention comprises 4.5 to 75 parts by weight of component A, 0.5 to 30 parts by weight of component B, and 20 to 95 parts by weight of component C (where component A + component B + component C = 100 parts by weight), and the extruded open cell foam can be manufactured stably. In the interest of obtaining foam exhibiting higher expansion ratio, broad width, and high thickness, and also in the

interest of restraining heat generation caused by the high viscosity of resin during extrusion foaming, moreover, it is preferable that component A be 5 parts by weight or greater but less than 50 parts by weight, that component B  
5 be 1 to 30 parts by weight, and that component C be 20 to 90 parts by weight (where component A + component B + component C = 100 parts by weight), and, in the interest of obtaining even more outstanding foam cell uniformity and less permanent compressive strain, it is particularly  
10 preferable that the component A be 10 to 45 parts by weight, component B 1 to 15 parts by weight, and component C 40 to 70 parts by weight (where component A + component B + component C = 100 parts by weight).

In this invention, when the component A noted in the  
15 foregoing is less than 4.5 parts by weight, a closed cell foam is formed at a resin extrusion temperature wherewith a foam is obtained, and the targeted foam cannot be obtained even by making the extrusion temperature higher in an effort to obtain open cell foam. When the component A  
20 exceeds 75 parts by weight, on the other hand, heat generation in the die becomes severe, and it is very difficult to obtain extruded open cell foam of high thickness and high expansion ratio.

When component B is less than 0.5 parts by weight, moreover, the shape retention effect in the cells configuring the foam becomes small and it becomes very difficult to obtain extruded open cell foam exhibiting a  
5 high expansion ratio and high wall thickness having uniform physical properties, and, particularly in a thick foam, cell uniformity is lost and giant cells are generated.

When component B exceeds 30 parts by weight, on the other hand, foamability is impaired, and good extruded open cell  
10 foam cannot be obtained.

When component C is less than 20 parts by weight, there will be little quantity of component of low melt tension in the vicinity of the foaming temperature, making it very difficult to obtain extruded open cell foam. When  
15 component C exceeds 95 parts by weight, on the other hand, closed cell foam forms readily, and it becomes very difficult to obtain extruded open cell foam.

The extruded polyolefin resin foam of the present invention has an open cell foaming ratio of 50% or higher.  
20 When the open cell foaming ratio is less than 50%, certain effects manifest by the peculiar functions exhibited by the extruded open cell foam, such as restorability after repeated stress, cushioning properties, flexibility, sound absorption, water absorption, and gas permeability, are

lessened, and it becomes difficult to deal with an open cell foam in terms of function and physical properties. By the open cell foaming ratio of the extruded open cell foam in the present invention, moreover, is meant not just a  
5 value for a portion of the foam, but an average value for the foam overall. Accordingly, even if in one part of the extruded open cell foam there is a portion that falls below the open cell foaming ratio specified in the present invention, that is permissible so long as the average value  
10 for the foam overall is equal to or higher than the open cell foaming ratio specified in the present invention.

In the interest of making the restorability after repeated stress, cushioning properties, flexibility, sound absorption, water absorption, and gas permeability that are  
15 properties peculiar to extruded open cell foams particularly outstanding, the open cell foaming ratio should be 70% or higher and preferably 80% or higher. When the open cell foaming ratio is 70% or higher, the foam becomes extremely soft to the touch, and clearly differs  
20 from foam having an open cell foaming ratio below 70%.

The open cell foaming ratio in the present invention is measured as noted below, in accordance with ASTM D-2856-70 (procedure C).



The true volume  $V_x$  ( $\text{cm}^3$ ) of the measurement specimen is found using an air pycnometer, the apparent volume  $V_a$  ( $\text{cm}^3$ ) of the measurement specimen is found from the outer dimensions thereof, and the open cell foaming ratio (%) is calculated by formula 1 below. By true volume  $V_x$  is meant the sum of the volume of the resin and the volume of the closed cell portion in the measurement specimen.

Formula 1

Open cell foaming ratio (%) =  $\{(V_a - V_x)/(V_a - W/\rho)\} \times 100$

where  $W$  is the weight (g) of the measurement specimen, and  $\rho$  is the density ( $\text{g}/\text{cm}^3$ ) of the base resin configuring the foam.

The dimensions of the measurement specimen is 25 mm longitudinally, 25 mm laterally, and 40 mm in thickness.

The extruded foam of the present invention, as described subsequently, can be configured in a sheet-form, plank-form, or rod-shaped form, in every which case samples are formed by cutting to the prescribed dimensions. In such cases, if a specimen having dimensions matching the dimensions of the measurement specimen described above cannot be obtained from one cutout sample, then multiple cutout samples are combined to prepare one measurement specimen. If, for example, one cutout sample were 25 mm longitudinally, 25 mm

laterally, and 20 mm in thickness, then two cutout samples having these dimensions would be stacked together to prepare a measurement specimen measuring 25 mm longitudinally, 25 mm laterally, and 40 mm in thickness.

5 Multiple sampling sites for the measurement specimens are established (preferably 10 or more sites), the open cell foaming ratio for each of those multiple measurement specimens obtained is found and the average value thereof calculated, and that average value is made the open cell  
10 foaming ratio of the extruded foam of the present invention.

The main component in the base resin of the extruded open cell foam of the present invention is a mixed polymer configured of a component A consisting of an ethylene ionomer resin, a component B consisting of a polyolefin  
15 resin having a melting point exceeding 120°C, and a component C consisting of one or two or more polymers selected from a group of ethylene-propylene rubbers, styrene elastomers, and polyethylene resins having melting points of 120°C or lower. In the present invention,  
20 furthermore, by saying that the mixed polymer is the main component in the base resin is meant that the mixed polymer is contained in an amount that at least exceeds 50 wt.% of the base resin configuring the extruded open cell foam, but

preferably 75 wt.% or more, and even more preferably 90 wt.% or more.

Accordingly, besides the mixed polymer consisting of the components A, B, and C noted above, a conventionally known resin or rubber or the like can be mixed, within a range of up to but not including 50 wt.%, in the base resin of the extruded open cell foam of the present invention, among which those with which a polymer composition of a denatured polyolefin polymer such as an ethylene-maleic acid anhydride-ethyl acrylate terpolymer or ethylene-butene-1 copolymer and a hydroxyl group containing polymer such as hydroxyl group ended polybutadiene hydrogenation product, methacrylic acid 2-hydroxyethyl graft ethylene-butene-1 copolymer, or low molecular weight polyolefin polyol are mixed, wherewith the crosslinked structure is weakened by heating, having so-called heat reversible crosslinked structures, being particularly preferred because therewith compressive elasticity is enhanced, and outstanding extruded open cell foam exhibiting little permanent compressive strain is formed.

By the ethylene ionomer resin configuring component A of the base resin in the present invention is meant a metal salt crosslinked compound of a copolymer between an ethylene monomer and an  $\alpha$  or  $\beta$  unsaturated carboxylic acid

such as acrylic acid, methacrylic acid, itaconic acid, maleic acid, fumaric acid, or cinnamic acid, etc. Examples of such metal salts that may be cited include alkali metal salts, alkali earth metal salts, typical metal salts, and  
5 transition metal salts. Metal salt crosslinked compounds of these polymers form a type of crosslinked structure between molecules by the ionic bonding force of the metal ions, whereby physical properties like those of crosslinked molecules are exhibited at room temperature, but  
10 processability like that of a non-crosslinked polymer is exhibited at the high temperatures where extrusion molding is possible.

Specific examples of such ethylene ionomer resins that may be cited include ionomer resins wherein crosslinking is  
15 effected by metal ions between the molecules of such copolymers as ethylene-acrylic acid copolymer, ethylene-acrylic acid-methylacrylate copolymer, ethylene-acrylic acid-ethylacrylate copolymer, ethylene-methacrylic acid-methylacrylate copolymer, ethylene-methacrylic acid-  
20 ethylacrylate copolymer, or ethylene-methacrylic acid copolymer, etc. Nor is the ethylene ionomer resin limited to a single resin, but may be one wherein two or more ethylene ionomer resins have been mixed.

The component B comprising the polyolefin resin having a melting point exceeding 120°C that configures the base resin in the present invention may be a polyethylene resin, polypropylene resin, or polybutene resin or the like. For the polyethylene resin noted here, polyethylenes having a density of 940 kg/m<sup>3</sup> or greater, and linear low-density polyethylenes and the like may be cited. For the polyolefin resin in component B, of the resins noted above, either one type or a mixture of two or more types of polypropylene resin linear low-density polyethylene or polyethylene having a density of 940 kg/m<sup>3</sup> or greater is preferable. By the component B, the range of suitable foaming temperatures during extraction foaming is broadened and it becomes possible to stably manufacture good extruded open cell foam.

The polyethylene resin having a melting point exceeding 120°C that configures the component B noted earlier is an ethylene homo-polymer or a copolymer between ethylene, on the one hand, and an  $\alpha$ -olefin having 3 to 12 carbons or the like, on the other, wherein the ethylene component is contained in an amount of 50 wt.% or more. Specific examples thereof that may be cited include high-density polyethylenes, medium-density polyethylenes, linear

low-density polyethylenes, ethylene-anhydrous maleic acid copolymers, ethylene-butene copolymers, ethylene-vinyl alcohols, and ethylene-glycidyl methacrylates, etc, respectively having a melting point exceeding 120°C.

- 5 Furthermore, the polyethylene resin is not limited to a single resin but may be one wherein two or more types of polyethylene resin have been mixed.

- By a polypropylene resin having a melting point exceeding 120°C configuring the component B is meant a
- 10 propylene homo-polymer or a copolymer between propylene, on the one hand, and another monomer component on the other, wherein the propylene component is contained in an amount that is 50 wt.% or greater. That copolymer may be a random copolymer, a block copolymer, or a graft copolymer.
- 15 Examples of the other monomer component configuring the copolymer that may be cited include ethylene, 1-butene, isobutylene, 1-pentene, 3-methyl-1-butene, 1-hexene, 3,4-dimethyl-1-butene, 1-pentene, and 3-methyl-1-hexene, etc. Furthermore, the polypropylene resin is not limited to a
- 20 single resin but may be one wherein two or more polypropylene resins have been mixed.

For the component B in the present invention, moreover, not only may a polyethylene resin, polypropylene resin, or

polybutene resin or the like be used singly, but a mixture of two or more types thereof may be used.

The component C configuring the base resin in the present invention is one or two or more types of polymer selected from among the group of ethylene-propylene rubbers, styrene elastomers, and polyethylene resins having a melting point of 120°C or lower.

The polyethylene resin having a melting point of 120° or lower configuring the component C is an ethylene homopolymer or a copolymer between ethylene, on the one hand, and an  $\alpha$ -olefin having 3 to 12 carbons or the like, on the other, wherein the ethylene component is contained in an amount of 50 wt.% or greater. Specific examples thereof that may be cited include low-density polyethylenes, medium-density polyethylenes, linear low-density polyethylenes, very low-density polyethylenes, ethylene-anhydrous maleic acid copolymers, ethylene-butene copolymers, ethylene-vinyl alcohols, ethylene-glycidyl methacrylates, ethylene- $\alpha$  or  $\beta$  unsaturated carboxylic acid copolymers (but excluding ionomers), and ethylene-vinyl acetate copolymers, having a melting point of 120°C or lower. Furthermore, this polyethylene resin is not limited to a single resin, but use may be made of one wherein two

or more types have been mixed. Among these polyethylene resins, one type or a mixed resin of two or more types selected from among the low-density polyethylenes, ethylene- $\alpha$  or  $\beta$  unsaturated carboxylic acid copolymers (but  
5 excluding ionomers), and ethylene-vinyl acetate copolymers is particularly to be preferred.

For the  $\alpha$ , or  $\beta$  unsaturated carboxylic acid component of the ethylene- $\alpha$ , or  $\beta$  unsaturated carboxylic acid copolymer in the polyethylene resins having a melting point  
10 of 120°C or lower, acrylic acid, methacrylic acid, itaconic acid, maleic acid, fumaric acid, and cinnamic acid, together with alkyl esters and the like thereof may be cited, of which, from the perspective of general-purposefulness, acrylic acid, methacrylic acid, and alkyl  
15 esters thereof are to be preferred.

The ethylene- $\alpha$  or  $\beta$  unsaturated carboxylic acids noted above are obtained by copolymerizing ethylene with the  $\alpha$  or  $\beta$  unsaturated carboxylic acid component. More specifically, ethylene-acrylic acid copolymers, ethylene-methyl acrylate  
20 copolymers, ethylene-ethyl acrylate copolymers, ethylene-methacrylic acid copolymers, ethylene-methyl methacrylate copolymers, and ethylene-ethyl methacrylate copolymers and the like may be cited. The content ratio for the  $\alpha$  or  $\beta$



unsaturated carboxylic acid in the ethylene- $\alpha$  or  $\beta$  unsaturated carboxylic acid copolymer noted above should be 2 to 50 wt.%, with 10 to 40 wt.% being particularly to be preferred.

5        For the ethylene-vinyl acetate copolymer in the polyethylene resin having a melting point of 120°C or lower, the vinyl acetate content prefers to be 5 to 50 wt.%. Because the difference in viscosity with the component A is appropriate, extruded open cell foam can be obtained with  
10 even greater stability in the extraction process.

      In the present invention, the melting point of the polyolefin resin configuring the component B and of the polyethylene resin configuring the component C is made the temperature at the apex of a peak found from test pieces  
15 subjected to a certain heat treatment according to the heat flux DSC curve based on JIS K7121 (1987). When two or more peaks appear, the temperature at the apex of the main peak having the largest peak area is made the melting point. The density of the polyethylene resin of the component B is  
20 found according to JIS K7112 (1980).

      Citable examples for the styrene propylene rubber configuring the component C include ethylene-propylene copolymers and ethylene-propylene-diene copolymers.

Citable examples for the ethylene elastomer configuring the component C include styrene-butadiene-styrene block copolymers (SBS), styrene-isoprene-styrene block copolymers (SIS), styrene-ethylene copolymers, 5 styrene-ethylene-propylene copolymers, SBS hydrogenation product, and SIS hydrogenation product, etc.

In the present invention, furthermore, various kinds of additives such as anti-shrinking agents, foam regulators, weather-resisting agents, UV radiation absorbers, UV 10 radiation reflectors, infrared radiation absorbers, infrared radiation reflectors, flame retardants, lubricants, colorants, thermal stabilizers, anti-oxidants, crystallization nucleating agents, inorganic fillers, and rubbers, etc., can be suitably mixed into the base resin as 15 necessary.

In the present invention, among the additives noted above, in particular, it is preferable that 0.1 to 15 parts by weight of an anti-shrinking agent be added to 100 parts by weight of the base resin because thereby it is possible 20 to obtain good foam, especially foam exhibiting a high expansion ratio and high thickness.

Citable examples of this anti-shrinking agent include esters of a fatty acid having 10 or more but preferably from 15 to 25 carbons and a polyvalent alcohol having 3 to

7 hydroxyl groups, fatty acid amines having 10 or more but preferably from 15 to 25 carbons, and fatty acid amides having 10 or more but preferably from 15 to 25 carbons, etc.

For the fatty acid having 10 or more carbons in the  
5 anti-shrinking agent noted above, stearic acid, oleic acid, lauric acid, behenic acid, lignoceric acid, cerotic acid, heptaconic acid, montanic acid, melissic acid, and laccelic acid, etc., may be cited, while for the polyvalent alcohol  
10 having 3 to 7 hydroxyl groups, glycerin, diglycerin, triglycerin, erythritol, arabitol, xylitol, mannitol, sorbitol, and sorbitan may be cited. For the anti-shrinking agent, moreover, a mixture of two or more anti-shrinking agents may also be used.

Specific examples of anti-shrinking agents that may be  
15 cited include glyceryl monostearate, glyceryl monobehenate, glyceryl distearate, glyceryl tristearate, polyoxyethylene myristyl amine, polyoxyethylene palmitin amine, polyoxyethylene stearyl amine, lauric acid amide, myristic acid amide, palmitic acid amide, and stearic acid amide,  
20 etc.

Examples of the foam regulator noted above that may be cited include fine powdered forms of such inorganic substances as talc, silica, and clay, etc., and such carbonate or bicarbonate salts as alkali metal salts of

polyvalent carboxylic acid such as sodium hydrogen tartrate, potassium hydrogen succinate, sodium citrate, potassium citrate, sodium bicarbonate, sodium carbonate, and sodium oxalate, etc., which prefer to be added in an amount of  
5 0.01 to 10 parts by weight to 100 parts by weight of the base resin.

For the foaming agent used in the manufacture of the extruded open cell foam of the present invention, either a physical foaming agent or a decomposing type foaming agent  
10 can be used, but the use of a physical foaming agent is preferred in order to obtain extruded open cell foam of high expansion ratio. For a physical foaming agent, fatty hydrocarbons such as propane, normal butane, isobutane, normal pentane, isopentane, normal hexane, isohexane, and  
15 cyclohexane, etc, such chloro-hydrocarbons as methyl chloride and ethyl chloride, such fluoro-hydrocarbons as 1,1,1,2-tetrafluoroethane and 1,1-difluoroethane, etc and such inorganic substances as carbon dioxide, nitrogen, and water, etc may be cited. For a decomposing type foaming  
20 agent, azodicarbonamide and the like may be cited. The foaming agents noted above can be used in mixtures of two or more, and a decomposing type foaming agent may be used together with a physical foaming agent and thus serve also to regulate the cell diameter.

The extruded open cell foam of the present invention prefers to have a density of 15 to 200 kg/m<sup>3</sup> and a thickness of 0.5 to 200 mm, configured either as sheet-form foam or plank-form foam. Nor is this foam limited to a flat form, but may be configured as rod-shaped foam. The form of the rod-shaped foam may be cross-sectionally hollow or cross-sectionally solid. When the extruded open cell foam of the present invention is sheet-form foam, the sheet-form foam prefers to have a density of 15 to 200 kg/m<sup>3</sup> and better still 15 to 60 kg/m<sup>3</sup>, and a thickness of 0.5 mm or greater but less than 10 mm. The width of the sheet-form foam prefers to be 45 cm or greater, and more preferably with 90 cm or greater, and with an upper limit for the width of 190 cm or so. Sheet-form foam so configured exhibits outstanding flexibility and makes ideal packaging material. It is also possible to subject this foam to such processing as bag fabrication or thermoforming or the like, for use as bags, fruit trays, or other containers. This foam can be used in a wide variety of applications including partitioning materials obtained by performing stamping processing or cutting processing on laminated sheet wherein materials exhibiting shape retention such as other polypropylene resin foam sheet or polystyrene resin foam sheet are integrally laminated, and

packaging containers such as fruit packaging materials or precision instrument packaging containers exhibiting high shock-absorption obtained by thermoforming such laminated sheet.

5       When the extruded open cell foam of the present invention is plank-form foam, the density prefers to be 15 to 100 kg/m<sup>3</sup> and the thickness 10 to 200 mm. The width of the plank-form foam should be at least 8 cm, with 25 cm or greater being preferable, and with an upper limit on the width of 150 cm or so. Plank-form foam so configured is ideal for shock absorbing pads, sound absorbing materials, and cushion materials and the like. In particular, when compared to the soft urethane open cell foam used conventionally as a cushion material, the plank-form foam of the present invention exhibits mild compressive strain (the deforming speed being slower than that of ordinary soft urethane), which property is an outstanding property deserving particular mention for applications such as cushion material. This plank-form foam can be made into any desired shape, to suit the application, by stamping processing or cutting processing.

When the extruded open cell foam of the present invention is rod-shaped foam, the density prefers to be 15 to 100 kg/m<sup>3</sup>, and the area of the cross-section

perpendicular to the direction of extrusion prefers to be  
0.7 cm<sup>2</sup> or greater and more preferably from 1 to 900 cm<sup>2</sup>.  
When the rod-shaped foam has a hollow cross-section, it is  
configured in a cylindrical shape, whereas when the rod-  
5 shaped foam has a solid cross-section, it is configured in  
a columnar shape. By forming cut creases in the  
longitudinal direction of the cylindrically shaped foam,  
use as shock-protecting material for pipes and columns and  
the like is possible, while the foam of the columnar shape  
10 can be used as packing and sealing material, taking  
advantage of the delayed restoration property (the fact  
that the speed of shape restoration after compression  
deformation is slower than that of ordinary soft urethane)  
peculiar to such foam. It is also easy to obtain cushion  
15 material and the like of large volume by joining the side  
surfaces of many rod-shaped foam bodies together.

In the present invention, the thickness and density of  
the extruded open cell foam are measured as described below.  
That is, for the thickness of the extruded open cell foam,  
20 the thickness of the foam is measured at ten points at  
equal intervals from one edge to the other edge in the  
width dimension, and the arithmetic mean of those ten  
points is taken. For the density of the extruded open cell  
foam, the weight (g) of a test piece that is 5 cm

longitudinally, 5 cm across, and the thickness of the foam is measured, the volume (cm<sup>3</sup>) of the test piece is next found from the outer dimensions of the test piece, and the quotient obtained by dividing the weight (g) of the test  
5 piece by the volume thereof is converted to kg/m<sup>3</sup> units.

The extruded open cell foam of the present invention can be obtained by taking the base resin noted earlier, such additives as anti-shrinking agents or foaming regulators such as talc which are added as necessary,  
10 supplying those to an extruder, subjecting those materials to melting under heating and kneading, then supplying a foaming agent and forming a foaming molten resin mixture, then regulating the extrusion resin temperature, pressure inside the extrusion die, and discharge volume, etc., and  
15 extruding the mixture from the die attached to the tip of the extruder into a low-pressure region and causing foaming. For the method of mixing the components A, B, and C and the additives, a known method can be adopted such as the method of dry-blending the mixture components, or the method of  
20 using a screw feeder of the like to introduce each of the mixture components from an extruder raw material supply port and mixing them together inside the extruder.

By selecting the die attached to the tip of the extruder according to the shape of the foam intended,



moreover, extruded open cell foam of various shapes can be manufactured, whether sheet-form foam, plank-form foam, or rod-shaped foam, etc. If a circular die is attached, for example, sheet-form foam can be obtained, whereas if a flat  
5 die is attached, plank-form foam can be obtained, and if a die having a hole matching the cross-sectional shape of the rod bodies is attached, rod-shaped foam can be obtained that is cylindrical or columnar or the like, but if a many-holed die is attached, cord-shaped foam or foam having a  
10 wide perpendicular cross-section at right angles to the direction of extrusion wherein multiple rod-shaped foam body side surfaces are fused together can be obtained, and if dies of different shape are attached then foam bodies having different cross-sectional shapes can be manufactured.

15 Also, if necessary, an apparatus (accumulator) may be installed wherewith the foaming molten resin mixture is accumulated between the extruder and the die or inside the die under conditions of high temperature and high pressure, and, after a prescribed volume has accumulated, that  
20 mixture is extruded from the die all at once using a movable ram. By installing an accumulator, the discharge speed can be increased dramatically, wherefore, even if the extruder is small, the foam of the present invention having

high expansion ratio and high thickness can be obtained, especially foam that is plank-form or rod-shaped.

In the present invention, extruded open cell foam wherein the open cell foaming ratio is 50% or greater can  
5 be formed, as described above, by supplying the base resin and foaming agent and the like to an extruder, heating, melting, and kneading those materials to form a foaming molten resin mixture, and then adjusting the extrusion resin temperature to be within a suitable foaming  
10 temperature range. That is, the foaming molten resin mixture wherein the extrusion resin temperature has been adjusted to be within a suitable foaming temperature range exhibits visco-elasticity that resists the foaming power of the foaming agent, so that the mixture foams uniformly, and,  
15 at the stage where cell walls are formed, the component C consisting of the polyolefin resin having a melting point of 120°C or lower and the like cannot follow the stretch of the component A and component B noted earlier, the softening point is low compared to the component A and  
20 component B, and a decline in visco-elasticity of component C causes the cell walls to rupture, whereupon open cell foaming occurs evenly. Even if cell wall destruction occurs, caused by the reduced visco-elasticity of component C, the cell shapes themselves are preserved, due to the

sufficient visco-elasticity of the component A. It is further thought that, in the present invention, the component B is also contained in the base resin, wherefore the molten viscosity enhancing effect due to the  
5 crystallization of the component B after foaming leads to an enhancement in the rigidity of the cells that configure the foam, that in turn results in reinforcing the cell shape retaining function of the component A, as a consequence whereof the suitable foaming temperature range  
10 wherein the extruded open cell foam is stably obtained is broadened.

Specifically, the extrusion resin temperature prefers to be adjusted within a range of 100 to 140°C, and more preferably to within a range of 110 to 130°C. When the  
15 extrusion resin temperature is below 100°C, the elastic force of the component A and the component C at the time of foaming will be too strong, whereupon it has possibility that extruded open cell foam having a high expansion ratio can not obtain it.

20 When the extrusion resin temperature exceeds 140°C, on the other hand, it has possibility that such problems arising as that the obtained foam will tend to shrink, or that giant cells will tend to be produced in the foam.

The open cell foaming ratio of the extruded open cell foam can be regulated by such methods as that of selecting the polymer in the component C in the base resin described earlier, that of adding a lubricant to the polymer of the component C, or that of adjusting the viscosity of the component C.

In the present invention, after manufacturing the extruded open cell foam having an open cell foaming ratio of 50% or greater, the open cell foaming ratio of the foam can be raised further by a secondary process such as one employing the method of subjecting the foam to a pin-hole process, piercing it with needles or the like, or one employing the method of destroying cell walls by expansion under heat, or by compression or the like.

The present invention is now described in even greater detail with the citation of embodiments.

The densities, melt flow rates, and melting points of the resins and polymers used are noted in Table 1.

The values given in Table 1 for the melt flow rate (MFR) were measured at a temperature of 190°C, under a load of 21.18 N, according to JIS K7210 (1976).

Table 1

	Resin	Product Name	Manufacturer	Density (kg/m <sup>3</sup> )	MFR (g/10min)	Melting point (°C)
Resin A	Ionomer	Himilan AM7316	DuPont-Mitsui Polychemicals	950	1.3	74.6
Resin B	HDPE	Idemitsu DH 210JZ	Idemitsu Petrochemical	968	5.0	133.6
Resin C	LLDPE	ULTZEK 3550R	Mitsui Petrochemical Industries	935	4.5	123.5
Resin D	PP	Idemitsu PP J700GP	Idemitsu Petrochemical	900	8.0	162.5
Resin E	PP	SUN-ALLOMER PM620A	SunAllomer	900	8.0	149.0
Resin F	LDPE	SUMIKATHENE F101-1	Sumitomo Chemical	922	0.3	110.3
Resin G	LDPE	NUC 8008	Nippon Unicar	917	4.7	107.9
Resin H	EMMA	Acryft WK307	Sumitomo Chemical	940	7.0	76.4
Resin I	EMMA	Acryft WK402	Sumitomo Chemical	940	20.0	73.9
Resin J	VLDPE	EXCELLEN VL EUL731	Sumitomo Chemical	895	10.0	108.6
Resin K	EMAA	NUCREL AN4318	DuPont-Mitsui Polychemicals	940	31.0	78.1

## Notes:

- 5 Ionomer: Ethylene-methacrylic acid-acrylic-acid ester  
terpolymer metal salts cross-linked compound

HDPE: High-density polyethylene

LLDPE: Linear low-density polyethylene

PP: Polypropylene homopolymer

LDPE: Low-density polyethylene

EMMA: Ethylene-methyl methacrylate copolymer (ethylene  
content = 75%)

VLDPE: Linear very low-density polyethylene

5 EMMA: Ethylene-methacrylic acid copolymer (ethylene  
content = 92%)

#### Embodiment 1

Raw material obtained by mixing 100 parts by weight of  
10 a mixed resin into which were mixed 38 parts by weight of  
"resin A," 5 parts by weight of "resin B," and 57 parts by  
weight of "resin G," 2 parts by weight of a foaming  
regulator master batch in which 5 parts by weight of sodium  
citrate and 10 parts by weight of talc were mixed for 100  
15 parts by weight of the low-density polyethylene "resin G,"  
and 10 parts by weight of an anti-shrinking agent master  
batch in which 12 parts by weight of glyceryl monostearate  
were mixed for 100 parts by weight of the low-density  
polyethylene "resin G," was supplied to a tandem type  
20 extruder having a first extruder with a caliber of 50 mm  
and a second extruder with a caliber of 65 mm connected by  
a crossbar passage, heated, and kneaded to make a molten  
resin, after which isobutane was pressure-injected and  
kneaded into the resin inside the extruder, as a physical

foaming agent, at a ratio of 8 parts by weight to 100 parts by weight of the mixed resin, to make the foaming molten material. Next, the molten material melted and kneaded inside the extruder was extruded from flat dies having a slit width of 30 mm and slit interval of 3 mm to yield plank-form extruded open cell foam.

The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, and the results indicated, respectively, in Table 2.

#### Cell Uniformity Evaluation:

- ... No giant cells or crushed cells are observed in the center part of the cross-section of the foam, and cell shape is uniform.
- 15 Δ ... Cell shape in the cross-section of the foam is unevenness.
- x ... Giant cells or crushed cells are observed in the center part of the cross-section of the foam.

#### Manufacturing Stability Evaluation:

- 20 ○ ... Density variation across a temperature width of 3°C or more in the foaming temperature range is less than 5 kg/m<sup>3</sup>, and the variation in open cell foaming

ratio across a temperature width of 3°C or more in the foaming temperature range is 5% or lower.

x ... Everything not meeting the criteria noted above.

The average cell diameters given in the table are  
5 values arrived at by drawing a straight line crossing the entire thickness of the foam in the thickness dimension, based on photographs obtained from cross-sections perpendicular to the foam extrusion direction or width dimension, counting the number of cells intersecting that  
10 straight line, and dividing the foam thickness (mm) by the number of cells so obtained.



Table 2

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
Mixed Resin Type	Foaming Temperature (°C)	Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Ionomer /HDPE/LDPE (Resin A / Resin B / Resin G)	117	38.8	100	1.28	33.4	100.0	○	○
	118	38.5	100	1.30	33.8	100.2	○	
	119	36.2	100	1.25	35.3	98.4	○	
	120	37.7	100	1.18	35.3	98.3	○	
	121	35.9	100	1.28	35.9	98.3	○	

**Embodiment 2**

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 38 parts by weight of "resin A," 5 parts by weight of "resin B," and 57 parts by weight of "resin H." The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 3.

Table 3

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
Mixed Resin Type	Foaming Temperature (°C)	Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Ionomer /HDPE/EMA (Resin A / Resin B / Resin H)	118	46.2	98	0.93	30.1	97.2	○	○
	119	46.7	97	0.95	29.9	95.2	○	
	120	48.7	98	0.90	29.4	92.4	○	
	121	49.3	99	0.94	29.0	92.2	○	

## Embodiment 3

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by  
5 mixing 38 parts by weight of "resin A," 5 parts by weight of "resin B," 28.5 parts by weight of "resin F," and 28.5 parts by weight of "resin I." The density, open cell  
foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the  
10 foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 4.

Table 4

Base Resin	Foaming Conditions	Physical Properties of Foam					Call Uniformity	Manufacturing Stability
Mixed Resin Type	Foaming Temperature (°C)	Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Ionomer /HDPE/LDPE /EMA (Resin A / Resin B / Resin F / Resin I)	117	34.4	96	1.33	39.1	104.0	○	○
	118	34.3	97	1.30	39.6	101.2	○	
	119	36.8	100	1.23	37.8	101.4	○	
	120	36.0	96	1.25	37.0	99.4	○	
	121	35.6	98	1.32	36.8	96.2	○	

## Embodiment 4

Raw material obtained by mixing 100 parts by weight of a mixed resin into which were mixed 29 parts by weight of "resin A," 5 parts by weight of "resin B," 38 parts by weight of "resin F," and 28 parts by weight of "resin I," 2 parts by weight of a foaming regulator master batch in which 5 parts by weight of sodium citrate and 10 parts by weight of talc were mixed for 100 parts by weight of the low-density polyethylene "resin G," and 10 parts by weight of an anti-shrinking agent master batch in which 12 parts by weight of glyceryl monostearate were mixed for 100 parts by weight of the low-density polyethylene "resin G," was supplied to a tandem type extruder having a first extruder with a caliber of 50 mm and a second extruder with a caliber of 65 mm connected by a crossbar passage, heated, and kneaded to make a molten resin, after which isobutane was pressure-injected and kneaded inside the extruder, as a physical foaming agent, at a ratio of 5.8 parts by weight to 100 parts by weight of the mixed resin, the foaming molten material obtained was filled into and accumulated inside an accumulator having a caliber of 90 mm connected downstream from the second extruder, after which the foaming molten material was extruded all at once, by moving a movable ram, from the interior of the accumulator,

through flat dies having a slit width of 90 mm and slit interval of 3mm, to yield plank-form extruded open cell foam.

5 The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 5.

Table 5

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
Mixed Resin Type	Foaming Temperature (°C)	Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Ionomer /HDPE/LDPE /EMA (Resin A / Resin B / Resin F / Resin I)	115	43.7	97	1.27	45.9	267.6	○	○
	116	44.7	96	1.29	45.5	268.4	○	
	117	44.9	98	1.32	45.3	263.0	○	
	118	45.2	98	1.36	45.0	267.4	○	



## Embodiment 5

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 33.3 parts by weight of "resin A," 16.7 parts by weight of "resin B," 25 parts by weight of "resin F," and 25 parts by weight of "resin I." The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 6.

Table 6

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
		Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Mixed Resin Type  Ionomer /HDPE/LDPE /EMA (Resin A / Resin B / Resin F / Resin I)	121	44.8	99	1.20	28.1	93.0	○	○
	122	43.5	98	1.17	29.3	92.2	○	
	123	41.0	99	0.98	30.2	90.2	○	

## Embodiment 6

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by  
5 mixing 40 parts by weight of "resin A," 3 parts by weight of "resin B," 28.5 parts by weight of "resin F," and 28.5 parts by weight of "resin I", and 8.7 parts by weight of isobutane were pressure-injected and kneaded into 100 parts by weight of the mixed resin inside the extruder. The  
10 density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 7.

Table 7

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
		Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Mixed Resin Type  Ionomer /HDPE/LDPE /EMA (Resin A / Resin B / Resin F / Resin I)	120	31.0	95	1.32	43.5	107.6	○	○
	121	31.2	96	1.35	43.3	105.5	○	
	122	33.3	99	1.28	42.2	103.0	○	
	123	33.8	100	1.20	41.7	101.4	○	

## Embodiment 7

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 38 parts by weight of "resin A," 5 parts by weight of "resin B," 28.5 parts by weight of "resin F," and 28.5 parts by weight of "resin I", and 8.7 parts by weight of isobutane were pressure-injected and kneaded into 100 parts by weight of the mixed resin inside the extruder. The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 8.

Table 8

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
Mixed Resin Type	Foaming Temperature (°C)	Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Ionomer /HDPE/LDPE /EMA (Resin A / Resin B / Resin F / Resin I)	119	31.4	96	1.39	41.7	109.0	○	○
	120	30.9	96	1.42	42.2	108.4	○	
	121	31.1	97	1.34	42.6	106.4	○	
	122	31.0	99	1.36	43.3	106.2	○	
	123	31.8	99	1.36	42.4	105.4	○	

With Embodiment 7, in a foaming temperature range of 5°C or higher, the change in density is less than 5 kg/m<sup>3</sup>, and the change in open cell foaming ratio is 5% or less, outstanding manufacturing stability is exhibited, no cell crushing is seen in the center of the foam cross-section such as that seen in Comparative Example 3 (described subsequently), and outstanding cell uniformity is exhibited. It is seen that, with Embodiment 7, extruded open cell foam of low density and high foaming efficiency is obtained, even with the same amount of foaming agent as in Comparative Example 3.

#### Embodiment 8

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 38 parts by weight of "resin A," 5 parts by weight of "resin C," 28.5 parts by weight of "resin F," and 28.5 parts by weight of "resin I", and 8.7 parts by weight of isobutane were pressure-injected and kneaded into 100 parts by weight of the mixed resin inside the extruder. The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and

manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 9.



Table 9

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
		Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Mixed Resin Type  Ionomer /LLDPE/LDPE /EMMA (Resin A / Resin C / Resin F / Resin I)	118	41.0	96	1.20	41.0	105.2	○	○
	119	42.0	97	1.27	42.0	104.8	○	
	120	42.9	95	1.34	42.9	103.0	○	
	121	40.3	100	1.22	40.3	102.0	○	

## Embodiment 9

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 38 parts by weight of "resin A," 5 parts by weight of "resin D," 28.5 parts by weight of "resin F," and 28.5 parts by weight of "resin I", and 8.7 parts by weight of isobutane were pressure-injected and kneaded into 100 parts by weight of the mixed resin inside the extruder. The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 10.

Table 10

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
Mixed Resin Type	Foaming Temperature (°C)	Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Ionomer /PP/LDPE/EMA (Resin A / Resin D / Resin F / Resin I)	119	34.8	97	1.15	38.9	105.0	○	
	120	34.3	99	1.13	38.6	105.0	○	○
	121	36.8	100	1.04	37.1	104.5	○	

## Embodiment 10

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by  
5 mixing 38 parts by weight of "resin A," 5 parts by weight of "resin E," 28.5 parts by weight of "resin F," and 28.5 parts by weight of "resin I", and 8.7 parts by weight of isobutane were pressure-injected and kneaded into 100 parts by weight of the mixed resin inside the extruder. The  
10 density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 11.



## Embodiment 11

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by  
5 mixing 29 parts by weight of "resin A," 5 parts by weight of "resin B," 37 parts by weight of "resin F," and 29 parts by weight of "resin G." The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam  
10 cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 12.

Table 12

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
		Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Mixed Resin Type	Foaming Temperature (°C)							
Ionomer /HDPE/LDPE /LDPE (Resin A / Resin B / Resin F / Resin G)	117	42.9	92	1.23	29.2	99.0	○	○
	118	43.8	93	1.19	28.9	98.0	○	
	119	47.6	96	1.12	26.9	94.0	○	

## Embodiment 12

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 38 parts by weight of "resin A," 5 parts by weight of "resin B," 28.5 parts by weight of "resin F," and 28.5 parts by weight of "resin J." The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 13.



Table 13

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
		Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Mixed Resin Type  Ionomer /HDPE/LDPE /VLDPE (Resin A / Resin B / Resin F / Resin J)	119	34.8	92	1.27	36.8	97.4	○	○
	120	35.2	93	1.23	36.3	96.2	○	
	121	39.0	96	1.17	33.7	94.2	○	

## Embodiment 13

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by  
5 mixing 38 parts by weight of "resin A," 5 parts by weight of "resin B," 28.5 parts by weight of "resin F," and 28.5 parts by weight of "resin K." The density, open cell  
foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the  
10 foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 14.

Table 14

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
Mixed Resin Type	Foaming Temperature (°C)	Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Ionomer /HDPE/LDPE /EMA (Resin A / Resin B / Resin F / Resin K)	115	33.4	67	0.81	39.5	110.0	○	○
	116	33.1	68	0.79	39.7	110.2	○	
	117	32.9	68	0.82	39.8	108.2	○	
	118	33.2	68	0.95	40.2	108.0	○	
	119	33.0	68	0.93	40.4	108.0	○	
	120	33.4	70	0.90	40.3	106.2	○	
	121	33.6	71	0.92	40.6	104.0	○	

## Comparative Example 1

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by  
5 mixing 43 parts by weight of "resin A," and 57 parts by weight of "resin G." The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were  
10 evaluated as noted above, and the results indicated, respectively, in Table 15.

Table 15

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
		Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Mixed Resin Type	Foaming Temperature (°C)							
	115	37.7	100	1.41	34.9	101.4	△	○
	116	38.6	100	1.38	36.7	100.0	△	
Ionomer /LDPE (Resin A / Resin G)	117	36.5	100	1.43	37.5	99.6	△	

With Comparative Example 1, in a foaming temperature range of 3°C or higher, the change in density is less than 5 kg/m<sup>3</sup>, and the change in open cell foaming ratio is 5% or less. However, with Embodiment 1 that temperature range is broadened to 5°C or greater, and Embodiment 1 is recognized as exhibiting more outstanding manufacturing stability. Also, although the foam obtained in Comparative Example 1 is usable as a product, cell unevenness is observed very locally in the foam cross-section, wherefore the foam of Embodiment 1 exhibits more outstanding cell uniformity.

#### Comparative Example 2

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 43 parts by weight of "resin A," 28.5 parts by weight of "resin F," and 28.5 parts by weight of "resin I." The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 16.

Table 16

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
Mixed Resin Type	Foaming Temperature (°C)	Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Ionomer /LDPE/EMMA (Resin A / Resin F / Resin I)	115	36.0	86	1.26	40.9	102.4	○	×
	116	41.9	98	0.98	36.1	100.4	○	
	117	50.4	100	—	32.6	91.2	×	
	118	60.8	100	—	27.3	84.0	×	

("—" in table indicates no measurement made)

Comparative Example 2 is a comparative example for Embodiment 3. With Comparative Example 2, in a foaming temperature range of 3°C, the change in density is 5 kg/m<sup>3</sup> or greater, manufacturing stability is lacking, and cell crushing was observed in the center of the cross-section of the foam obtained at a foaming temperature of 117°C or higher.

#### Comparative Example 3

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 43 parts by weight of "resin A," 28.5 parts by weight of "resin F," and 28.5 parts by weight of "resin I," and 8.7 parts by weight of isobutane were pressure injected and kneaded into 100 parts by weight of the mixed resin inside the extruder. The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 17.



Table 17

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
		Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Mixed Resin Type  Ionomer / LDPE/EMA (Resin A / Resin F / Resin I)	117	31.8	76	1.68	43.9	102.0	○	×
	118	34.5	85	1.42	37.2	101.4	○	
	119	41.7	100	1.03	34.0	91.8	○	
	120	41.4	100	—	34.9	88.0	×	
	121	49.4	100	—	31.6	82.0	×	

("—" in table indicates no measurement made)

Comparative Example 3 is a comparative example for Embodiment 7. With Comparative Example 3, in a foaming temperature range of 3°C, the change in density is 5 kg/m<sup>3</sup> or greater, manufacturing stability is lacking, and cell  
5 crushing was observed in the center of the cross-section of the foam obtained at a foaming temperature of 120°C or higher.

#### Comparative Example 4

10 Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 34 parts by weight of "resin A," 37 parts by weight of "resin F," and 29 parts by weight of "resin G." The  
15 density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 18.

Table 18

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
Mixed Resin Type	Foaming Temperature (°C)	Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Ionomer /LDPE/LDPE (Resin A / Resin F / Resin G)	116	30.6	38	1.89	39.3	100.6	○	×
	117	40.2	78	—	33.4	97.0	△	
	118	48.2	95	—	25.5	92.2	△	
	119	57.6	100	—	19.5	80.6	△	

( "—" in table indicates no measurement made )

Comparative Example 4 is a comparative example for Embodiment 11. With Comparative Example 4, in a foaming temperature range of 3°C, the change in density exceeds 5 kg/m<sup>3</sup>, manufacturing stability is lacking, and portions of cell unevenness were observed in the cross-section of the foam obtained at a foaming temperature of 117°C or higher.

#### Comparative Example 5

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 43 parts by weight of "resin A," 28.5 parts by weight of "resin F," and 28.5 parts by weight of "resin J." The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 19.

Table 19

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
		Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Mixed Resin Type  Ionomer /LDPE/VLDPE (Resin A / Resin F / Resin J)	117	34.7	92	1.47	39.3	98.0	○	×
	118	42.4	98	0.90	33.4	90.0	○	
	119	60.3	100	0.62	25.5	68.6	×	

Comparative Example 5 is a comparative example for Embodiment 12. With Comparative Example 5, in a foaming temperature range of 3°C, the change in density is 5 kg/m<sup>3</sup> or greater, manufacturing stability is lacking, and cell crushing was observed in the center of the cross-section of the foam obtained at a foaming temperature of 119°C or higher.

#### Comparative Example 6

10       An attempt was made to obtain rod-shaped extruded open cell foam with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 5 parts by weight of "resin B," 67 parts by weight of "resin F," and 28 parts by weight of "resin H,"  
15       and in that the die was made 4mm  $\phi$  rod die, but no foam was obtained.

Below, the compressive strengths of the foams obtained in Embodiments 6 to 9 and Comparative Example 3 are given in Table 20, and the defection set by constant compression  
20       and defection set by repeated compressions of the foams obtained in Embodiments 6 to 10 and Comparative Example 3 are given in Tables 21 and 22, respectively. The methods

of testing for compressive strength and permanent compressive strain were as described below.

Compressive strength:

Static compression tests were performed in accordance with JIS Z0234 (1976) Method A. The dimensions of the test pieces were made 50 mm longitudinally x 50 mm across x the thickness of the foam and the load speed was made 10 mm/minute. After compressing the test piece to 80% of its thickness, the compression was released at the same speed as the load speed, and measurement was concluded at the point in time where the compressive stress became 0 Pa, to yield a stress-strain curve. The loads at the time of 5% compression and at the time of 25% compression, respectively, were read from the curve obtained, and the 5% compressive strength and 25% compressive strength were calculated therefrom.

Deflection set by constant compression:

Except in that the conditions of the test atmosphere were made 23°C temperature and 50% relative humidity, deflection set by constant compression tests were performed according to JIS K6401 (1980). The dimensions of the test pieces were made 50 mm longitudinally x 50 mm across x the thickness of the foam. The test piece was compressed to

50% and left standing in that condition for 22 hours, after which the compression was released. The thickness of the test piece was then measured, 30 minutes later and 24 hours later, respectively, and the percentage of defection set by  
5 constant compression was calculated.

Defection set by repeated compressions:

Except in that the conditions of the test atmosphere were made 23°C temperature and 50% relative humidity, defection set by repeated compressions tests were performed  
10 according to JIS K6401 (1980). The dimensions of the test pieces were made 50 mm longitudinally x 50 mm across x the thickness of the foam. The test piece was subjected to 80,000 continuously repeated compressions to 50% of the thickness thereof, at a speed of 60 revolution/minute.  
15 Then the thickness of the test piece was measured, 30 minutes and 24 hours after the compression was released, respectively, and the percentage of defection set by repeated compressions was calculated therefrom.



Table 20

	5% Compressive Strength (kPa)	25% Compressive Strength (kPa)
Embodiment 6	5.16	9.41
Embodiment 7	6.09	10.36
Embodiment 8	4.32	8.21
Embodiment 9	5.91	10.37
Comparative Example 3	4.45	7.66

5

Table 21

	Percentage of deflection set by constant compression After 30 Minutes(%)	Percentage of deflection set by constant compression After 24 Hours(%)
Embodiment 6	6.8	2.0
Embodiment 7	7.4	2.2
Embodiment 8	4.4	2.3
Embodiment 9	6.1	1.8
Embodiment 10	4.9	1.1
Comparative Example 3	3.4	1.0

Table 22

	Percentage of defection set by repeated compressions After 30 Minutes(%)	Percentage of defection set by repeated compressions After 24 Hours(%)
Embodiment 6	10.7	3.8
Embodiment 7	10.9	4.5
Embodiment 8	9.0	3.1
Embodiment 9	8.3	2.6
Embodiment 10	7.8	2.4
Comparative Example 3	5.4	2.8

5

INDUSTRIAL APPLICABILITY

The extruded polyolefin resin foam of the present invention exhibits a high expansion ratio, uniform cell diameter, and outstanding mechanical properties, and is well suited for use as cushion material, packaging material, sound absorbing material, water absorbing material, anti-vibration material, and various types of industrial filter.

10

CLAIMS

1. An extruded polyolefin resin foam, characterized  
in that said extruded polyolefin resin foam is an extruded  
5 foam exhibiting an open cell ratio of 50% or greater, and  
that base resin thereof is principally composed of a mixed  
polymer consisting of 4.5 to 75 parts by weight of  
component A consisting of an ethylene ionomer resin, 0.5 to  
30 parts by weight of component B consisting of a  
10 polyolefin resin having a melting point exceeding 120°C,  
and 20 to 95 parts by weight of component C consisting of  
one or two or more polymers selected from a group of  
ethylene-propylene rubbers, styrene elastomers, and  
polyethylene resins having melting points of 120°C or lower  
15 (where component A + component B + component C = 100 parts  
by weight).

2. The extruded polyolefin resin foam according to  
claim 1, characterized in that said component B consisting  
of a polyolefin resin having a melting point exceeding  
20 120°C is one type or a mixed resin of two or more types  
selected from among polypropylene resin, linear low-density  
polyethylenes, and polyethylene resins having a density of  
940 kg/m<sup>3</sup> or greater.

3. The extruded polyolefin resin foam according to claim 1, characterized in that said polyethylene resin having a melting point of 120°C or lower in said component C is one type or a mixed resin of two or more types
- 5 selected from among low-density polyethylenes, ethylene- $\alpha$  or  $\beta$  unsaturated carboxylic acid copolymers (but excluding ionomers), and ethylene-vinyl acetate copolymers.
4. The extruded polyolefin resin foam according to claim 1, characterized in that 0.1 to 15 parts by weight of
- 10 an anti-shrinking agent are added to 100 parts by weight of said base resin.
5. The extruded polyolefin resin foam according to claim 1 or claim 4, characterized in that said extruded foam has a density of 15 to 200 kg/m<sup>3</sup> and a thickness of
- 15 0.5 to 200 mm.
6. The extruded polyolefin resin foam according to claim 1 or claim 4, characterized in that said extruded foam is sheet-form foam or plank-form foam.
7. The extruded polyolefin resin foam according to
- 20 claim 1 or claim 4, characterized in that said extruded foam is rod-shaped foam having a density of 15 to 100 kg/m<sup>3</sup>, and area of vertical cross-section thereof orthogonal to direction of extrusion being 0.7 cm<sup>2</sup> or greater.

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(54) Title: EXTRUDED POLYOLEFIN RESIN FOAM

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# INTERNATIONAL SEARCH REPORT

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**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 636 473 A (ALKOR GMBH) 1 February 1995 (1995-02-01) page 7; example 1; table claims	1-7
A	US 5 110 842 A (TAKEDA MASASHI ET AL) 5 May 1992 (1992-05-05) table 1A claims	1-7

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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## DESCRIPTION

### EXTRUDED POLYOLEFIN RESIN FOAM

## TECHNICAL FIELD

5        This invention relates to extruded polyolefin resin foam used in cushion material, packaging material, sound absorbing material, water absorbing material, anti-vibration material, and various kinds of industrial filters, etc.

10

## BACKGROUND ART

      The open cell foams made of synthetic resins known to the prior art include urethane foams, foam rubber, and ethylene-vinyl acetate copolymer foams, etc. These foams, because they are flexible and exhibit good processability, have been used in such applications as cleaning sponges, shock absorbing materials, cushion materials, sound absorbing materials, and various industrial filters. Nevertheless, applications for these open cell extruded foams have been limited due to their inferiority in terms of chemical resistance (acid resistance, alkali resistance, etc.) and weatherability. Furthermore, urethane foams and foam rubber are very difficult to recycle back to raw materials, while ethylene-vinyl acetate copolymer foams are

problematic because of their large amount of foul odor during manufacture.

Polyolefin resins, on the other hand, exhibit very outstanding chemical resistance and weatherability, as well as outstanding recyclability. Accordingly, the problems noted above can be overcome if the open cell extruded foam is made of a polyolefin resin.

That being so, attempts have been made before to develop open cell polyolefin resin foams. Art is known, for example, for subjecting a closed cell polyolefin resin foam to pinhole processing to form open cell foam. However, open cell polyolefin resin foams obtained by simply subjecting closed cell foams made from polyethylene resin or polypropylene resin base material to pinhole processing exhibit high permanent compression set, and do not have sufficient shock-absorbing properties to stand up under prolonged use.

Other methods have also been reported, such as that described in Japanese Patent Publication No. S60-55290/1985 which uses a mixture of low-density polyethylene and high-density polyethylene, and that described in Japanese Patent Application Laid-Open No. 2000-7817 which uses a mixture of low-fluidity and high-fluidity low-density polyethylenes as the base resin for obtaining an open cell extruded foam.

With those methods, however, foam of sufficient thickness, width, and expansion ratio are not obtained, nor do such foams exhibit adequate practical usability. Also known are open cell foams made of polyolefin resins and ionomer resins. In Japanese Patent Application Laid-Open No. H10-279724/1998, for example, a foam is disclosed wherein for 0 to 50 parts by weight of a polyolefin resin are used 100 to 50 parts by weight of a costly ionomer resin. However, when foam extrusion of an open cell foam of such mixture as noted above is performed, the extrusion pressure is high, wherefore heat generation at the die is severe, making it very difficult to obtain good open cell extruded foams exhibiting a high expansion ratio and high thickness. In addition, the molten resin setting temperature (hereinafter called the foaming temperature) must be regulated within a narrow range during extrusion foaming in order to obtain the open cell extruded foam, making stable manufacture difficult. Also, in Japanese Patent Application Laid-Open No. 59-196384/1994, a foam wherein for 100 parts by weight of a polyolefin resin, 60 to 150 parts by weight of an ionomer resin are used, but this is small rod-shaped foam having a cross-sectional area of 0.1 cm<sup>2</sup> or so which is used as core material in sealers used in window frames and the like, for example.

In Japanese Patent Application No. 2000-23179, an open cell extruded foam is described wherein a mixture of two or three or more polyolefin resins having different melting points is used as the base resin. More specifically, in  
5 this patent application, an open cell extruded foam is described, the main component whereof is a mixed polymer configured by a component consisting of a polyolefin resin, and a component consisting either of one or two or more polymers selected from a group made up of ethylene- $\alpha$ , or  $\beta$   
10 unsaturated carboxylic acid copolymers (but excluding ionomers), olefin elastomers, styrene elastomers, and ethylene-vinyl acetate copolymers, or of such mixed polymer to which a heat reversible crosslinked polymer has been added.

15 With the resin mixture described above, the range of suitable foaming temperatures wherewith the open cell foam can be stably obtained is narrow, and, if the foaming temperature is higher than the suitable foaming temperatures, the foam contracts, making it difficult to  
20 obtain foam having the desired expansion ratio and thickness, whereas, if the foaming temperature is lower than the suitable foaming temperatures, the closed cell foaming ratio rises and the desired open cell foam is not obtained. If an attempt is made to obtain an open cell

foam of high foaming expansion ratio, moreover, the cell wall thickness of the foam becomes thin, it becomes very difficult to retain the shape of the open cell foamed cell walls during extrusion foaming, and good foam is difficult  
5 to obtain.

Thus, in the prior art, it has been very difficult to stably manufacture foam exhibiting uniform physical product properties, and to stably manufacture polyolefin resin open cell extruded foam exhibiting high expansion ratio and high  
10 open cell foaming ratio, especially thick product exhibiting uniform physical properties.

With the foregoing in view, it is an object of the present invention to provide extruded open cell foam of uniform physical product properties, with a high expansion  
15 ratio, and uniform cell diameter, particularly such extruded open cell foam that is thick.

#### DISCLOSURE OF THE INVENTION

The present invention is an extruded polyolefin resin  
20 open cell foam having an open cell foaming ratio of 50% or higher. The base resin of the foam of the present invention has as its main component a mixed polymer consisting of 4.5 to 75 parts by weight of a component A consisting of an ethylene ionomer resin, 0.5 to 30 parts by

weight of a component B consisting of a polyolefin resin having a melting point exceeding 120°C, and 20 to 95 parts by weight of a component C consisting of one or two or more polymers selected from a group of ethylene-propylene rubbers, styrene elastomers, and polyethylene resins having melting points of 120°C or lower (where component A + component B + component C = 100 parts by weight).

The component B consisting of the polyolefin resin having a melting point exceeding 120°C should be one or two or more mixed resins selected from among polypropylene resin, linear low-density polyethylenes, and polyethylene resins having a density of 940 kg/m<sup>3</sup> or greater.

The polyethylene resin having a melting point of 120°C or lower in component C should be one or two or more mixed resins selected from among low-density polyethylenes, ethylene- $\alpha$ , or  $\beta$  unsaturated carboxylic acid copolymers (but excluding ionomers), and ethylene-vinyl acetate copolymers.

An anti-shrinking agent can be added to the base resin, whereupon the amount added should be 0.1 to 15 parts by weight for 100 parts by weight of the basic resin.

The extruded open cell foam of the present invention should have a density of 15 to 200 kg/m<sup>3</sup> and thickness of

0.5 to 200 mm, which can be configured either as sheet-form foam or plank-form foam. The shape is not limited to a flat shape, however, and rod-shaped foam can also be configured. The form of the rod shapes may be either one  
5 with a hollow cross-section or solid cross-section, with a density of 15 to 100 kg/m<sup>3</sup> and an area of cross-section (perpendicular to direction of extrusion) of 0.7 cm<sup>2</sup> or greater being preferred.

Based on the present invention, in an extruded open  
10 cell foam of broad width, or an extruded open cell foam of large thickness, having a high expansion ratio, good foam is realized with uniform cell diameter and little partial variation in mechanical properties. In the present invention, furthermore, by adding the base resin configured  
15 as described in the foregoing, particularly by adding a specific amount of the polyolefin resin having a melting point exceeding 120°C of component B, to the components A and C, benefits are realized in that the range of suitable foaming temperature for stably obtaining the extruded open  
20 cell foam broadens, manufacture of the extruded open cell foam is made easy, and product yield can be improved.

BEST MODE FOR CARRYING OUT THE INVENTION

The extruded polyolefin resin foam of the present invention is an extruded polyolefin resin open cell foam having an open cell foaming ratio of 50% or higher. The base resin for this extruded open cell foam has as its main component a mixed polymer consisting of 4.5 to 75 parts by weight of a component A consisting of an ethylene ionomer resin, 0.5 to 30 parts by weight of a component B consisting of a polyolefin resin having a melting point exceeding 120°C, and 20 to 95 parts by weight of a component C consisting of one or two or more polymers selected from a group of ethylene-propylene rubbers, styrene elastomers, and polyethylene resins having melting points of 120°C or lower (where component A + component B + component C = 100 parts by weight).

15       The mixed polymer that is the main component in the base resin configuring the extruded open cell foam of the present invention comprises 4.5 to 75 parts by weight of component A, 0.5 to 30 parts by weight of component B, and 20 to 95 parts by weight of component C (where component A + component B + component C = 100 parts by weight), and the extruded open cell foam can be manufactured stably. In the interest of obtaining foam exhibiting higher expansion ratio, broad width, and high thickness, and also in the



interest of restraining heat generation caused by the high viscosity of resin during extrusion foaming, moreover, it is preferable that component A be 5 parts by weight or greater but less than 50 parts by weight, that component B  
5 be 1 to 30 parts by weight, and that component C be 20 to 90 parts by weight (where component A + component B + component C = 100 parts by weight), and, in the interest of obtaining even more outstanding foam cell uniformity and less permanent compressive strain, it is particularly  
10 preferable that the component A be 10 to 45 parts by weight, component B 1 to 15 parts by weight, and component C 40 to 70 parts by weight (where component A + component B + component C = 100 parts by weight).

In this invention, when the component A noted in the  
15 foregoing is less than 4.5 parts by weight, a closed cell foam is formed at a resin extrusion temperature wherewith a foam is obtained, and the targeted foam cannot be obtained even by making the extrusion temperature higher in an effort to obtain open cell foam. When the component A  
20 exceeds 75 parts by weight, on the other hand, heat generation in the die becomes severe, and it is very difficult to obtain extruded open cell foam of high thickness and high expansion ratio.

When component B is less than 0.5 parts by weight, moreover, the shape retention effect in the cells configuring the foam becomes small and it becomes very difficult to obtain extruded open cell foam exhibiting a  
5 high expansion ratio and high wall thickness having uniform physical properties, and, particularly in a thick foam, cell uniformity is lost and giant cells are generated. When component B exceeds 30 parts by weight, on the other hand, foamability is impaired, and good extruded open cell  
10 foam cannot be obtained.

When component C is less than 20 parts by weight, there will be little quantity of component of low melt tension in the vicinity of the foaming temperature, making it very difficult to obtain extruded open cell foam. When  
15 component C exceeds 95 parts by weight, on the other hand, closed cell foam forms readily, and it becomes very difficult to obtain extruded open cell foam.

The extruded polyolefin resin foam of the present invention has an open cell foaming ratio of 50% or higher.  
20 When the open cell foaming ratio is less than 50%, certain effects manifest by the peculiar functions exhibited by the extruded open cell foam, such as restorability after repeated stress, cushioning properties, flexibility, sound absorption, water absorption, and gas permeability, are

lessened, and it becomes difficult to deal with an open cell foam in terms of function and physical properties. By the open cell foaming ratio of the extruded open cell foam in the present invention, moreover, is meant not just a  
5 value for a portion of the foam, but an average value for the foam overall. Accordingly, even if in one part of the extruded open cell foam there is a portion that falls below the open cell foaming ratio specified in the present invention, that is permissible so long as the average value  
10 for the foam overall is equal to or higher than the open cell foaming ratio specified in the present invention.

In the interest of making the restorability after repeated stress, cushioning properties, flexibility, sound absorption, water absorption, and gas permeability that are  
15 properties peculiar to extruded open cell foams particularly outstanding, the open cell foaming ratio should be 70% or higher and preferably 80% or higher. When the open cell foaming ratio is 70% or higher, the foam becomes extremely soft to the touch, and clearly differs  
20 from foam having an open cell foaming ratio below 70%.

The open cell foaming ratio in the present invention is measured as noted below, in accordance with ASTM D-2856-70 (procedure C).

The true volume  $V_x$  ( $\text{cm}^3$ ) of the measurement specimen is found using an air pycnometer, the apparent volume  $V_a$  ( $\text{cm}^3$ ) of the measurement specimen is found from the outer dimensions thereof, and the open cell foaming ratio (%) is calculated by formula 1 below. By true volume  $V_x$  is meant the sum of the volume of the resin and the volume of the closed cell portion in the measurement specimen.

Formula 1

$$\text{Open cell foaming ratio (\%)} = \{(V_a - V_x) / (V_a - W/\rho)\} \times 100$$

where  $W$  is the weight (g) of the measurement specimen, and  $\rho$  is the density ( $\text{g}/\text{cm}^3$ ) of the base resin configuring the foam.

The dimensions of the measurement specimen is 25 mm longitudinally, 25 mm laterally, and 40 mm in thickness.

The extruded foam of the present invention, as described subsequently, can be configured in a sheet-form, plank-form, or rod-shaped form, in every which case samples are formed by cutting to the prescribed dimensions. In such cases, if a specimen having dimensions matching the dimensions of the measurement specimen described above cannot be obtained from one cutout sample, then multiple cutout samples are combined to prepare one measurement specimen. If, for example, one cutout sample were 25 mm longitudinally, 25 mm

laterally, and 20 mm in thickness, then two cutout samples having these dimensions would be stacked together to prepare a measurement specimen measuring 25 mm longitudinally, 25 mm laterally, and 40 mm in thickness.

5 Multiple sampling sites for the measurement specimens are established (preferably 10 or more sites), the open cell foaming ratio for each of those multiple measurement specimens obtained is found and the average value thereof calculated, and that average value is made the open cell  
10 foaming ratio of the extruded foam of the present invention.

The main component in the base resin of the extruded open cell foam of the present invention is a mixed polymer configured of a component A consisting of an ethylene ionomer resin, a component B consisting of a polyolefin  
15 resin having a melting point exceeding 120°C, and a component C consisting of one or two or more polymers selected from a group of ethylene-propylene rubbers, styrene elastomers, and polyethylene resins having melting points of 120°C or lower. In the present invention,  
20 furthermore, by saying that the mixed polymer is the main component in the base resin is meant that the mixed polymer is contained in an amount that at least exceeds 50 wt.% of the base resin configuring the extruded open cell foam, but

preferably 75 wt.% or more, and even more preferably 90 wt.% or more.

Accordingly, besides the mixed polymer consisting of the components A, B, and C noted above, a conventionally known resin or rubber or the like can be mixed, within a range of up to but not including 50 wt.%, in the base resin of the extruded open cell foam of the present invention, among which those with which a polymer composition of a denatured polyolefin polymer such as an ethylene-maleic acid anhydride-ethyl acrylate terpolymer or ethylene-butene-1 copolymer and a hydroxyl group containing polymer such as hydroxyl group ended polybutadiene hydrogenation product, methacrylic acid 2-hydroxyethyl graft ethylene-butene-1 copolymer, or low molecular weight polyolefin polyol are mixed, wherewith the crosslinked structure is weakened by heating, having so-called heat reversible crosslinked structures, being particularly preferred because therewith compressive elasticity is enhanced, and outstanding extruded open cell foam exhibiting little permanent compressive strain is formed.

By the ethylene ionomer resin configuring component A of the base resin in the present invention is meant a metal salt crosslinked compound of a copolymer between an ethylene monomer and an  $\alpha$  or  $\beta$  unsaturated carboxylic acid

such as acrylic acid, methacrylic acid, itaconic acid, maleic acid, fumaric acid, or cinnamic acid, etc. Examples of such metal salts that may be cited include alkali metal salts, alkali earth metal salts, typical metal salts, and  
5 transition metal salts. Metal salt crosslinked compounds of these polymers form a type of crosslinked structure between molecules by the ionic bonding force of the metal ions, whereby physical properties like those of crosslinked molecules are exhibited at room temperature, but  
10 processability like that of a non-crosslinked polymer is exhibited at the high temperatures where extrusion molding is possible.

Specific examples of such ethylene ionomer resins that may be cited include ionomer resins wherein crosslinking is  
15 effected by metal ions between the molecules of such copolymers as ethylene-acrylic acid copolymer, ethylene-acrylic acid-methylacrylate copolymer, ethylene-acrylic acid-ethylacrylate copolymer, ethylene-methacrylic acid-methylacrylate copolymer, ethylene-methacrylic acid-  
20 ethylacrylate copolymer, or ethylene-methacrylic acid copolymer, etc. Nor is the ethylene ionomer resin limited to a single resin, but may be one wherein two or more ethylene ionomer resins have been mixed.

The component B comprising the polyolefin resin having a melting point exceeding 120°C that configures the base resin in the present invention may be a polyethylene resin, polypropylene resin, or polybutene resin or the like. For the polyethylene resin noted here, polyethylenes having a density of 940 kg/m<sup>3</sup> or greater, and linear low-density polyethylenes and the like may be cited. For the polyolefin resin in component B, of the resins noted above, either one type or a mixture of two or more types of polypropylene resin linear low-density polyethylene or polyethylene having a density of 940 kg/m<sup>3</sup> or greater is preferable. By the component B, the range of suitable foaming temperatures during extraction foaming is broadened and it becomes possible to stably manufacture good extruded open cell foam.

The polyethylene resin having a melting point exceeding 120°C that configures the component B noted earlier is an ethylene homo-polymer or a copolymer between ethylene, on the one hand, and an  $\alpha$ -olefin having 3 to 12 carbons or the like, on the other, wherein the ethylene component is contained in an amount of 50 wt.% or more. Specific examples thereof that may be cited include high-density polyethylenes, medium-density polyethylenes, linear



low-density polyethylenes, ethylene-anhydrous maleic acid copolymers, ethylene-butene copolymers, ethylene-vinyl alcohols, and ethylene-glycidyl methacrylates, etc, respectively having a melting point exceeding 120°C.

- 5 Furthermore, the polyethylene resin is not limited to a single resin but may be one wherein two or more types of polyethylene resin have been mixed.

- By a polypropylene resin having a melting point exceeding 120°C configuring the component B is meant a
- 10 propylene homo-polymer or a copolymer between propylene, on the one hand, and another monomer component on the other, wherein the propylene component is contained in an amount that is 50 wt.% or greater. That copolymer may be a random copolymer, a block copolymer, or a graft copolymer.
- 15 Examples of the other monomer component configuring the copolymer that may be cited include ethylene, 1-butene, isobutylene, 1-pentene, 3-methyl-1-butene, 1-hexene, 3,4-dimethyl-1-butene, 1-pentene, and 3-methyl-1-hexene, etc. Furthermore, the polypropylene resin is not limited to a
- 20 single resin but may be one wherein two or more polypropylene resins have been mixed.

For the component B in the present invention, moreover, not only may a polyethylene resin, polypropylene resin, or

polybutene resin or the like be used singly, but a mixture of two or more types thereof may be used.

The component C configuring the base resin in the present invention is one or two or more types of polymer  
5 selected from among the group of ethylene-propylene rubbers, styrene elastomers, and polyethylene resins having a melting point of 120°C or lower.

The polyethylene resin having a melting point of 120° or lower configuring the component C is an ethylene homo-  
10 polymer or a copolymer between ethylene, on the one hand, and an  $\alpha$ -olefin having 3 to 12 carbons or the like, on the other, wherein the ethylene component is contained in an amount of 50 wt.% or greater. Specific examples thereof that may be cited include low-density polyethylenes,  
15 medium-density polyethylenes, linear low-density polyethylenes, very low-density polyethylenes, ethylene-anhydrous maleic acid copolymers, ethylene-butene copolymers, ethylene-vinyl alcohols, ethylene-glycidyl methacrylates, ethylene- $\alpha$  or  $\beta$  unsaturated carboxylic acid  
20 copolymers (but excluding ionomers), and ethylene-vinyl acetate copolymers, having a melting point of 120°C or lower. Furthermore, this polyethylene resin is not limited to a single resin, but use may be made of one wherein two

or more types have been mixed. Among these polyethylene resins, one type or a mixed resin of two or more types selected from among the low-density polyethylenes, ethylene- $\alpha$  or  $\beta$  unsaturated carboxylic acid copolymers (but  
5 excluding ionomers), and ethylene-vinyl acetate copolymers is particularly to be preferred.

For the  $\alpha$ , or  $\beta$  unsaturated carboxylic acid component of the ethylene- $\alpha$ , or  $\beta$  unsaturated carboxylic acid copolymer in the polyethylene resins having a melting point  
10 of 120°C or lower, acrylic acid, methacrylic acid, itaconic acid, maleic acid, fumaric acid, and cinnamic acid, together with alkyl esters and the like thereof may be cited, of which, from the perspective of general-purposefulness, acrylic acid, methacrylic acid, and alkyl  
15 esters thereof are to be preferred.

The ethylene- $\alpha$  or  $\beta$  unsaturated carboxylic acids noted above are obtained by copolymerizing ethylene with the  $\alpha$  or  $\beta$  unsaturated carboxylic acid component. More specifically, ethylene-acrylic acid copolymers, ethylene-methyl acrylate  
20 copolymers, ethylene-ethyl acrylate copolymers, ethylene-methacrylic acid copolymers, ethylene-methyl methacrylate copolymers, and ethylene-ethyl methacrylate copolymers and the like may be cited. The content ratio for the  $\alpha$  or  $\beta$

unsaturated carboxylic acid in the ethylene- $\alpha$  or  $\beta$  unsaturated carboxylic acid copolymer noted above should be 2 to 50 wt.%, with 10 to 40 wt.% being particularly to be preferred.

5        For the ethylene-vinyl acetate copolymer in the polyethylene resin having a melting point of 120°C or lower, the vinyl acetate content prefers to be 5 to 50 wt.%. Because the difference in viscosity with the component A is appropriate, extruded open cell foam can be obtained with  
10 even greater stability in the extraction process.

In the present invention, the melting point of the polyolefin resin configuring the component B and of the polyethylene resin configuring the component C is made the temperature at the apex of a peak found from test pieces  
15 subjected to a certain heat treatment according to the heat flux DSC curve based on JIS K7121 (1987). When two or more peaks appear, the temperature at the apex of the main peak having the largest peak area is made the melting point. The density of the polyethylene resin of the component B is  
20 found according to JIS K7112 (1980).

Citable examples for the ethylene propylene rubber configuring the component C include ethylene-propylene copolymers and ethylene-propylene-diene copolymers.

Citable examples for the styrene elastomer configuring the component C include styrene-butadiene-styrene block copolymers (SBS), styrene-isoprene-styrene block copolymers (SIS), styrene-ethylene copolymers, styrene-ethylene-propylene copolymers, SBS hydrogenation product, and SIS hydrogenation product, etc.

In the present invention, furthermore, various kinds of additives such as anti-shrinking agents, foam regulators, weather-resisting agents, UV radiation absorbers, UV radiation reflectors, infrared radiation absorbers, infrared radiation reflectors, flame retardants, lubricants, colorants, thermal stabilizers, anti-oxidants, crystallization nucleating agents, inorganic fillers, and rubbers, etc., can be suitably mixed into the base resin as necessary.

In the present invention, among the additives noted above, in particular, it is preferable that 0.1 to 15 parts by weight of an anti-shrinking agent be added to 100 parts by weight of the base resin because thereby it is possible to obtain good foam, especially foam exhibiting a high expansion ratio and high thickness.

Citable examples of this anti-shrinking agent include esters of a fatty acid having 10 or more but preferably from 15 to 25 carbons and a polyvalent alcohol having 3 to

7 hydroxyl groups, fatty acid amines having 10 or more but preferably from 15 to 25 carbons, and fatty acid amides having 10 or more but preferably from 15 to 25 carbons, etc.

For the fatty acid having 10 or more carbons in the  
5 anti-shrinking agent noted above, stearic acid, oleic acid, lauric acid, behenic acid, lignoceric acid, cerotic acid, heptaconic acid, montanic acid, melissic acid, and laccelic acid, etc., may be cited, while for the polyvalent alcohol having 3 to 7 hydroxyl groups, glycerin, diglycerin,  
10 triglycerin, erythritol, arabitol, xylitol, mannitol, sorbitol, and sorbitan may be cited. For the anti-shrinking agent, moreover, a mixture of two or more anti-shrinking agents may also be used.

Specific examples of anti-shrinking agents that may be  
15 cited include glyceryl monostearate, glyceryl monobehenate, glyceryl distearate, glyceryl tristearate, polyoxyethylene myristyl amine, polyoxyethylene palmitin amine, polyoxyethylene stearyl amine, lauric acid amide, myristic acid amide, palmitic acid amide, and stearic acid amide,  
20 etc.

Examples of the foam regulator noted above that may be cited include fine powdered forms of such inorganic substances as talc, silica, and clay, etc., and such carbonate or bicarbonate salts as alkali metal salts of

polyvalent carboxylic acid such as sodium hydrogen tartrate, potassium hydrogen succinate, sodium citrate, potassium citrate, sodium bicarbonate, sodium carbonate, and sodium oxalate, etc., which prefer to be added in an amount of  
5 0.01 to 10 parts by weight to 100 parts by weight of the base resin.

For the foaming agent used in the manufacture of the extruded open cell foam of the present invention, either a physical foaming agent or a decomposing type foaming agent  
10 can be used, but the use of a physical foaming agent is preferred in order to obtain extruded open cell foam of high expansion ratio. For a physical foaming agent, fatty hydrocarbons such as propane, normal butane, isobutane, normal pentane, isopentane, normal hexane, isohexane, and  
15 cyclohexane, etc, such chloro-hydrocarbons as methyl chloride and ethyl chloride, such fluoro-hydrocarbons as 1,1,1,2-tetrafluoroethane and 1,1-difluoroethane, etc and such inorganic substances as carbon dioxide, nitrogen, and water, etc may be cited. For a decomposing type foaming  
20 agent, azodicarbonamide and the like may be cited. The foaming agents noted above can be used in mixtures of two or more, and a decomposing type foaming agent may be used together with a physical foaming agent and thus serve also to regulate the cell diameter.

The extruded open cell foam of the present invention prefers to have a density of 15 to 200 kg/m<sup>3</sup> and a thickness of 0.5 to 200 mm, configured either as sheet-form foam or plank-form foam. Nor is this foam limited to a flat form, but may be configured as rod-shaped foam. The form of the rod-shaped foam may be cross-sectionally hollow or cross-sectionally solid. When the extruded open cell foam of the present invention is sheet-form foam, the sheet-form foam prefers to have a density of 15 to 200 kg/m<sup>3</sup> and better still 15 to 60 kg/m<sup>3</sup>, and a thickness of 0.5 mm or greater but less than 10 mm. The width of the sheet-form foam prefers to be 45 cm or greater, and more preferably with 90 cm or greater, and with an upper limit for the width of 190 cm or so. Sheet-form foam so configured exhibits outstanding flexibility and makes ideal packaging material. It is also possible to subject this foam to such processing as bag fabrication or thermoforming or the like, for use as bags, fruit trays, or other containers. This foam can be used in a wide variety of applications including partitioning materials obtained by performing stamping processing or cutting processing on laminated sheet wherein materials exhibiting shape retention such as other polypropylene resin foam sheet or polystyrene resin foam sheet are integrally laminated, and



packaging containers such as fruit packaging materials or precision instrument packaging containers exhibiting high shock-absorption obtained by thermoforming such laminated sheet.

5       When the extruded open cell foam of the present invention is plank-form foam, the density prefers to be 15 to 100 kg/m<sup>3</sup> and the thickness 10 to 200 mm. The width of the plank-form foam should be at least 8 cm, with 25 cm or greater being preferable, and with an upper limit on the  
10 width of 150 cm or so. Plank-form foam so configured is ideal for shock absorbing pads, sound absorbing materials, and cushion materials and the like. In particular, when compared to the soft urethane open cell foam used conventionally as a cushion material, the plank-form foam  
15 of the present invention exhibits mild compressive strain (the deforming speed being slower than that of ordinary soft urethane), which property is an outstanding property deserving particular mention for applications such as cushion material. This plank-form foam can be made into  
20 any desired shape, to suit the application, by stamping processing or cutting processing.

When the extruded open cell foam of the present invention is rod-shaped foam, the density prefers to be 15 to 100 kg/m<sup>3</sup>, and the area of the cross-section

perpendicular to the direction of extrusion prefers to be 0.7 cm<sup>2</sup> or greater and more preferably from 1 to 900 cm<sup>2</sup>. When the rod-shaped foam has a hollow cross-section, it is configured in a cylindrical shape, whereas when the rod-shaped foam has a solid cross-section, it is configured in a columnar shape. By forming cut creases in the longitudinal direction of the cylindrically shaped foam, use as shock-protecting material for pipes and columns and the like is possible, while the foam of the columnar shape can be used as packing and sealing material, taking advantage of the delayed restoration property (the fact that the speed of shape restoration after compression deformation is slower than that of ordinary soft urethane) peculiar to such foam. It is also easy to obtain cushion material and the like of large volume by joining the side surfaces of many rod-shaped foam bodies together.

In the present invention, the thickness and density of the extruded open cell foam are measured as described below. That is, for the thickness of the extruded open cell foam, the thickness of the foam is measured at ten points at equal intervals from one edge to the other edge in the width dimension, and the arithmetic mean of those ten points is taken. For the density of the extruded open cell foam, the weight (g) of a test piece that is 5 cm

longitudinally, 5 cm across, and the thickness of the foam is measured, the volume ( $\text{cm}^3$ ) of the test piece is next found from the outer dimensions of the test piece, and the quotient obtained by dividing the weight (g) of the test  
5 piece by the volume thereof is converted to  $\text{kg/m}^3$  units.

The extruded open cell foam of the present invention can be obtained by taking the base resin noted earlier, such additives as anti-shrinking agents or foaming regulators such as talc which are added as necessary,  
10 supplying those to an extruder, subjecting those materials to melting under heating and kneading, then supplying a foaming agent and forming a foaming molten resin mixture, then regulating the extrusion resin temperature, pressure inside the extrusion die, and discharge volume, etc., and  
15 extruding the mixture from the die attached to the tip of the extruder into a low-pressure region and causing foaming. For the method of mixing the components A, B, and C and the additives, a known method can be adopted such as the method of dry-blending the mixture components, or the method of  
20 using a screw feeder of the like to introduce each of the mixture components from an extruder raw material supply port and mixing them together inside the extruder.

By selecting the die attached to the tip of the extruder according to the shape of the foam intended,

moreover, extruded open cell foam of various shapes can be manufactured, whether sheet-form foam, plank-form foam, or rod-shaped foam, etc. If a circular die is attached, for example, sheet-form foam can be obtained, whereas if a flat  
5 die is attached, plank-form foam can be obtained, and if a die having a hole matching the cross-sectional shape of the rod bodies is attached, rod-shaped foam can be obtained that is cylindrical or columnar or the like, but if a many-holed die is attached, cord-shaped foam or foam having a  
10 wide perpendicular cross-section at right angles to the direction of extrusion wherein multiple rod-shaped foam body side surfaces are fused together can be obtained, and if dies of different shape are attached then foam bodies having different cross-sectional shapes can be manufactured.

15 Also, if necessary, an apparatus (accumulator) may be installed wherewith the foaming molten resin mixture is accumulated between the extruder and the die or inside the die under conditions of high temperature and high pressure, and, after a prescribed volume has accumulated, that  
20 mixture is extruded from the die all at once using a movable ram. By installing an accumulator, the discharge speed can be increased dramatically, wherefore, even if the extruder is small, the foam of the present invention having

high expansion ratio and high thickness can be obtained, especially foam that is plank-form or rod-shaped.

In the present invention, extruded open cell foam wherein the open cell foaming ratio is 50% or greater can  
5 be formed, as described above, by supplying the base resin and foaming agent and the like to an extruder, heating, melting, and kneading those materials to form a foaming molten resin mixture, and then adjusting the extrusion resin temperature to be within a suitable foaming  
10 temperature range. That is, the foaming molten resin mixture wherein the extrusion resin temperature has been adjusted to be within a suitable foaming temperature range exhibits visco-elasticity that resists the foaming power of the foaming agent, so that the mixture foams uniformly, and,  
15 at the stage where cell walls are formed, the component C consisting of the polyolefin resin having a melting point of 120°C or lower and the like cannot follow the stretch of the component A and component B noted earlier, the softening point is low compared to the component A and  
20 component B, and a decline in visco-elasticity of component C causes the cell walls to rupture, whereupon open cell foaming occurs evenly. Even if cell wall destruction occurs, caused by the reduced visco-elasticity of component C, the cell shapes themselves are preserved, due to the

sufficient visco-elasticity of the component A. It is further thought that, in the present invention, the component B is also contained in the base resin, wherefore the molten viscosity enhancing effect due to the

5 crystallization of the component B after foaming leads to an enhancement in the rigidity of the cells that configure the foam, that in turn results in reinforcing the cell shape retaining function of the component A, as a consequence whereof the suitable foaming temperature range

10 wherein the extruded open cell foam is stably obtained is broadened.

Specifically, the extrusion resin temperature prefers to be adjusted within a range of 100 to 140°C, and more preferably to within a range of 110 to 130°C. When the

15 extrusion resin temperature is below 100°C, the elastic force of the component A and the component C at the time of foaming will be too strong, whereupon it has possibility that extruded open cell foam having a high expansion ratio can not obtain it.

20 When the extrusion resin temperature exceeds 140°C, on the other hand, it has possibility that such problems arising as that the obtained foam will tend to shrink, or that giant cells will tend to be produced in the foam.

The open cell foaming ratio of the extruded open cell foam can be regulated by such methods as that of selecting the polymer in the component C in the base resin described earlier, that of adding a lubricant to the polymer of the component C, or that of adjusting the viscosity of the component C.

In the present invention, after manufacturing the extruded open cell foam having an open cell foaming ratio of 50% or greater, the open cell foaming ratio of the foam can be raised further by a secondary process such as one employing the method of subjecting the foam to a pin-hole process, piercing it with needles or the like, or one employing the method of destroying cell walls by expansion under heat, or by compression or the like.

The present invention is now described in even greater detail with the citation of embodiments.

The densities, melt flow rates, and melting points of the resins and polymers used are noted in Table 1.

The values given in Table 1 for the melt flow rate (MFR) were measured at a temperature of 190°C, under a load of 21.18 N, according to JIS K7210 (1976).

Table 1

	Resin	Product Name	Manufacturer	Density (kg/m <sup>3</sup> )	MFR (g/10min)	Melting point (°C)
Resin A	Ionomer	Himilan AM7316	DuPont-Mitsui Polychemicals	950	1.3	74.6
Resin B	HDPE	Idemitsu DH 210JZ	Idemitsu Petrochemical	968	5.0	133.6
Resin C	LLDPE	ULTZEX 3550R	Mitsui Petrochemical Industries	935	4.5	123.5
Resin D	PP	Idemitsu PP J700GP	Idemitsu Petrochemical	900	8.0	162.5
Resin E	PP	SUN-ALLOMER PM620A	SunAllomer	900	8.0	149.0
Resin F	LDPE	SUMIKATHENE F101-1	Sumitomo Chemical	922	0.3	110.3
Resin G	LDPE	NUC 8008	Nippon Unicar	917	4.7	107.9
Resin H	EMMA	Acryft WK307	Sumitomo Chemical	940	7.0	76.4
Resin I	EMMA	Acryft WK402	Sumitomo Chemical	940	20.0	73.9
Resin J	VLDPE	EXCELLEN VL EUL731	Sumitomo Chemical	895	10.0	108.6
Resin K	EMAA	NUCREL AN4318	DuPont-Mitsui Polychemicals	940	31.0	78.1

## Notes:

- 5 Ionomer: Ethylene-methacrylic acid-acrylic-acid ester  
terpolymer metal salts cross-linked compound

HDPE: High-density polyethylene

LLDPE: Linear low-density polyethylene

PP: Polypropylene homopolymer



LDPE: Low-density polyethylene

EMMA: Ethylene-methyl methacrylate copolymer (ethylene  
content = 75%)

VLDPE: Linear very low-density polyethylene

5 EMAA: Ethylene-methacrylic acid copolymer (ethylene  
content = 92%)

#### Embodiment 1

Raw material obtained by mixing 100 parts by weight of  
10 a mixed resin into which were mixed 38 parts by weight of  
"resin A," 5 parts by weight of "resin B," and 57 parts by  
weight of "resin G," 2 parts by weight of a foaming  
regulator master batch in which 5 parts by weight of sodium  
citrate and 10 parts by weight of talc were mixed for 100  
15 parts by weight of the low-density polyethylene "resin G,"  
and 10 parts by weight of an anti-shrinking agent master  
batch in which 12 parts by weight of glyceryl monostearate  
were mixed for 100 parts by weight of the low-density  
polyethylene "resin G," was supplied to a tandem type  
20 extruder having a first extruder with a caliber of 50 mm  
and a second extruder with a caliber of 65 mm connected by  
a crossbar passage, heated, and kneaded to make a molten  
resin, after which isobutane was pressure-injected and  
kneaded into the resin inside the extruder, as a physical

foaming agent, at a ratio of 8 parts by weight to 100 parts by weight of the mixed resin, to make the foaming molten material. Next, the molten material melted and kneaded inside the extruder was extruded from flat dies having a slit width of 30 mm and slit interval of 3 mm to yield plank-form extruded open cell foam.

The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, and the results indicated, respectively, in Table 2.

#### Cell Uniformity Evaluation:

- ... No giant cells or crushed cells are observed in the center part of the cross-section of the foam, and cell shape is uniform.
- 15 Δ ... Cell shape in the cross-section of the foam is unevenness.
- ×
- ... Giant cells or crushed cells are observed in the center part of the cross-section of the foam.

#### Manufacturing Stability Evaluation:

- 20 ○ ... Density variation across a temperature width of 3°C or more in the foaming temperature range is less than 5 kg/m<sup>3</sup>, and the variation in open cell foaming

ratio across a temperature width of 3°C or more in  
the foaming temperature range is 5% or lower.

x ... Everything not meeting the criteria noted above.

The average cell diameters given in the table are  
5 values arrived at by drawing a straight line crossing the  
entire thickness of the foam in the thickness dimension,  
based on photographs obtained from cross-sections  
perpendicular to the foam extrusion direction or width  
dimension, counting the number of cells intersecting that  
10 straight line, and dividing the foam thickness (mm) by the  
number of cells so obtained.

Table 2

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
		Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Mixed Resin Type Ionomer / HDPE/LDPE (Resin A / Resin B / Resin G)	117	38.8	100	1.28	33.4	100.0	○	○
	118	38.5	100	1.30	33.8	100.2	○	
	119	36.2	100	1.25	35.3	98.4	○	
	120	37.7	100	1.18	35.3	98.3	○	
	121	35.9	100	1.28	35.9	98.3	○	

**Embodiment 2**

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 38 parts by weight of "resin A," 5 parts by weight of "resin B," and 57 parts by weight of "resin H." The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 3.

Table 3

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
		Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Mixed Resin Type	Foaming Temperature (°C)							
Ionomer /HDPE/EMA (Resin A / Resin B / Resin H)	118	46.2	98	0.93	30.1	97.2	○	○
	119	46.7	97	0.95	29.9	95.2	○	
	120	48.7	98	0.90	29.4	92.4	○	
	121	49.3	99	0.94	29.0	92.2	○	

## Embodiment 3

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by  
5 mixing 38 parts by weight of "resin A," 5 parts by weight of "resin B," 28.5 parts by weight of "resin F," and 28.5 parts by weight of "resin I." The density, open cell  
foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the  
10 foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 4.

Table 4

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
		Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Mixed Resin Type  Ionomer /HDPE/LDPE /EMA (Resin A / Resin B / Resin F / Resin I)	117	34.4	96	1.33	39.1	104.0	○	○
	118	34.3	97	1.30	39.6	101.2	○	
	119	36.8	100	1.23	37.8	101.4	○	
	120	36.0	96	1.25	37.0	99.4	○	
	121	35.6	98	1.32	36.8	96.2	○	



## Embodiment 4

Raw material obtained by mixing 100 parts by weight of a mixed resin into which were mixed 29 parts by weight of "resin A," 5 parts by weight of "resin B," 38 parts by weight of "resin F," and 28 parts by weight of "resin I," 2 parts by weight of a foaming regulator master batch in which 5 parts by weight of sodium citrate and 10 parts by weight of talc were mixed for 100 parts by weight of the low-density polyethylene "resin G," and 10 parts by weight of an anti-shrinking agent master batch in which 12 parts by weight of glyceryl monostearate were mixed for 100 parts by weight of the low-density polyethylene "resin G," was supplied to a tandem type extruder having a first extruder with a caliber of 50 mm and a second extruder with a caliber of 65 mm connected by a crossbar passage, heated, and kneaded to make a molten resin, after which isobutane was pressure-injected and kneaded inside the extruder, as a physical foaming agent, at a ratio of 5.8 parts by weight to 100 parts by weight of the mixed resin, the foaming molten material obtained was filled into and accumulated inside an accumulator having a caliber of 90 mm connected downstream from the second extruder, after which the foaming molten material was extruded all at once, by moving a movable ram, from the interior of the accumulator,

through flat dies having a slit width of 90 mm and slit interval of 3mm, to yield plank-form extruded open cell foam.

The density, open cell foaming ratio, average cell  
5 diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 5.

Table 5

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
		Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Mixed Resin Type  Ionomer /HDPE/LDPE /EMA (Resin A / Resin B / Resin F / Resin I)	115	43.7	97	1.27	45.9	267.6	○	○
	116	44.7	96	1.29	45.5	268.4	○	
	117	44.9	98	1.32	45.3	263.0	○	
	118	45.2	98	1.36	45.0	267.4	○	

## Embodiment 5

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 33.3 parts by weight of "resin A," 16.7 parts by weight of "resin B," 25 parts by weight of "resin F," and 25 parts by weight of "resin I." The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 6.

Table 6

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
Mixed Resin Type	Foaming Temperature (°C)	Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Ionomer /HDPE/LDPE /EMA (Resin A / Resin B / Resin F / Resin I)	121	44.8	99	1.20	28.1	93.0	○	○
	122	43.5	98	1.17	29.3	92.2	○	
	123	41.0	99	0.98	30.2	90.2	○	

## Embodiment 6

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 40 parts by weight of "resin A," 3 parts by weight of "resin B," 28.5 parts by weight of "resin F," and 28.5 parts by weight of "resin I", and 8.7 parts by weight of isobutane were pressure-injected and kneaded into 100 parts by weight of the mixed resin inside the extruder. The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 7.

Table 7

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
Mixed Resin Type	Foaming Temperature (°C)	Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Ionmer /HDPE/LDPE /EMA (Resin A / Resin B / Resin F / Resin I)	120	31.0	95	1.32	43.5	107.6	○	○
	121	31.2	96	1.35	43.3	105.5	○	
	122	33.3	99	1.28	42.2	103.0	○	
	123	33.8	100	1.20	41.7	101.4	○	

## Embodiment 7

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 38 parts by weight of "resin A," 5 parts by weight of "resin B," 28.5 parts by weight of "resin F," and 28.5 parts by weight of "resin I", and 8.7 parts by weight of isobutane were pressure-injected and kneaded into 100 parts by weight of the mixed resin inside the extruder. The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 8.



Table 8

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
		Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Mixed Resin Type  Ionomer / HDPE/LDPE / EMA (Resin A / Resin B / Resin F / Resin I)	119	31.4	96	1.39	41.7	109.0	○	○
	120	30.9	96	1.42	42.2	108.4	○	
	121	31.1	97	1.34	42.6	106.4	○	
	122	31.0	99	1.36	43.3	106.2	○	
	123	31.8	99	1.36	42.4	105.4	○	

With Embodiment 7, in a foaming temperature range of 5°C or higher, the change in density is less than 5 kg/m<sup>3</sup>, and the change in open cell foaming ratio is 5% or less, outstanding manufacturing stability is exhibited, no cell crushing is seen in the center of the foam cross-section such as that seen in Comparative Example 3 (described subsequently), and outstanding cell uniformity is exhibited. It is seen that, with Embodiment 7, extruded open cell foam of low density and high foaming efficiency is obtained, even with the same amount of foaming agent as in Comparative Example 3.

#### Embodiment 8

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 38 parts by weight of "resin A," 5 parts by weight of "resin C," 28.5 parts by weight of "resin F," and 28.5 parts by weight of "resin I", and 8.7 parts by weight of isobutane were pressure-injected and kneaded into 100 parts by weight of the mixed resin inside the extruder. The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and

manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 9.

Table 9

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
		Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Mixed Resin Type  Ionomer /LLDPE/LDPE /EVA (Resin A / Resin C / Resin F / Resin I)	118	41.0	96	1.20	41.0	105.2	○	○
	119	42.0	97	1.27	42.0	104.8	○	
	120	42.9	95	1.34	42.9	103.0	○	
	121	40.3	100	1.22	40.3	102.0	○	

**Embodiment 9**

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 38 parts by weight of "resin A," 5 parts by weight of "resin D," 28.5 parts by weight of "resin F," and 28.5 parts by weight of "resin I", and 8.7 parts by weight of isobutane were pressure-injected and kneaded into 100 parts by weight of the mixed resin inside the extruder. The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 10.

Table 10

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
Mixed Resin Type	Foaming Temperature (°C)	Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Ionomer /PP/LDPE/EMMA (Resin A / Resin D / Resin F / Resin I)	119	34.8	97	1.15	38.9	105.0	○	
	120	34.3	99	1.13	38.6	105.0	○	○
	121	36.8	100	1.04	37.1	104.5	○	

## Embodiment 10

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by  
5 mixing 38 parts by weight of "resin A," 5 parts by weight of "resin E," 28.5 parts by weight of "resin F," and 28.5 parts by weight of "resin I", and 8.7 parts by weight of isobutane were pressure-injected and kneaded into 100 parts by weight of the mixed resin inside the extruder. The  
10 density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 11.

Table 11

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
		Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Mixed Resin Type Ionomer / PP/LDPE/ EMA (Resin A / Resin E / Resin F / Resin I)	118	40.5	96	1.02	32.0	102.2	○	○
	119	38.3	100	1.08	33.9	100.0	○	
	120	37.9	100	1.12	34.4	100.2	○	



**Embodiment 11**

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by  
5 mixing 29 parts by weight of "resin A," 5 parts by weight of "resin B," 37 parts by weight of "resin F," and 29 parts by weight of "resin G." The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam  
10 cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 12.

Table 12

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
		Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Mixed Resin Type	Foaming Temperature (°C)							
Ionomer /HDPE/LDPE /LDPE (Resin A / Resin B / Resin F / Resin G)	117	42.9	92	1.23	29.2	99.0	○	○
	118	43.8	93	1.19	28.9	98.0	○	
	119	47.6	96	1.12	26.9	94.0	○	

**Embodiment 12**

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 38 parts by weight of "resin A," 5 parts by weight of "resin B," 28.5 parts by weight of "resin F," and 28.5 parts by weight of "resin J." The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 13.

Table 13

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
Mixed Resin Type	Foaming Temperature (°C)	Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Ionomer /HDPE/LDPE /VLDPE (Resin A / Resin B / Resin F / Resin J)	119	34.8	92	1.27	36.8	97.4	○	○
	120	35.2	93	1.23	36.3	96.2	○	
	121	39.0	96	1.17	33.7	94.2	○	

**Embodiment 13**

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by  
5 mixing 38 parts by weight of "resin A," 5 parts by weight of "resin B," 28.5 parts by weight of "resin F," and 28.5 parts by weight of "resin K." The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the  
10 foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 14.

Table 14

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
		Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Mixed Resin Type  Ionomer /HDPE/LDPE /EMAA (Resin A / Resin B / Resin F / Resin K)	115	33.4	67	0.81	39.5	110.0	○	○
	116	33.1	68	0.79	39.7	110.2	○	
	117	32.9	68	0.82	39.8	108.2	○	
	118	33.2	68	0.95	40.2	108.0	○	
	119	33.0	68	0.93	40.4	108.0	○	
	120	33.4	70	0.90	40.3	106.2	○	
	121	33.6	71	0.92	40.6	104.0	○	

### Comparative Example 1

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by  
5 mixing 43 parts by weight of "resin A," and 57 parts by weight of "resin G." The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were  
10 evaluated as noted above, and the results indicated, respectively, in Table 15.

Table 15

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
Mixed Resin Type	Foaming Temperature (°C)	Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Ionomer /LDPE (Resin A / Resin G)	115	37.7	100	1.41	34.9	101.4	△	○
	116	38.6	100	1.38	36.7	100.0	△	
	117	36.5	100	1.43	37.5	99.6	△	



With Comparative Example 1, in a foaming temperature range of 3°C or higher, the change in density is less than 5 kg/m<sup>3</sup>, and the change in open cell foaming ratio is 5% or less. However, with Embodiment 1 that temperature range is broadened to 5°C or greater, and Embodiment 1 is recognized as exhibiting more outstanding manufacturing stability. Also, although the foam obtained in Comparative Example 1 is usable as a product, cell unevenness is observed very locally in the foam cross-section, wherefore the foam of Embodiment 1 exhibits more outstanding cell uniformity.

#### Comparative Example 2

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 43 parts by weight of "resin A," 28.5 parts by weight of "resin F," and 28.5 parts by weight of "resin I." The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 16.

Table 16

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
		Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Mixed Resin Type  Ionomer /LDPE/EMA (Resin A / Resin F / Resin I)	115	36.0	86	1.26	40.9	102.4	○	×
	116	41.9	98	0.98	36.1	100.4	○	
	117	50.4	100	—	32.6	91.2	×	
	118	60.8	100	—	27.3	84.0	×	

("—" in table indicates no measurement made)

Comparative Example 2 is a comparative example for Embodiment 3. With Comparative Example 2, in a foaming temperature range of 3°C, the change in density is 5 kg/m<sup>3</sup> or greater, manufacturing stability is lacking, and cell  
5 crushing was observed in the center of the cross-section of the foam obtained at a foaming temperature of 117°C or higher.

#### Comparative Example 3

10 Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 43 parts by weight of "resin A," 28.5 parts by weight of "resin F," and 28.5 parts by weight of "resin I,"  
15 and 8.7 parts by weight of isobutane were pressure injected and kneaded into 100 parts by weight of the mixed resin inside the extruder. The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-  
20 sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 17.

Table 17

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
		Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Mixed Resin Type  Ionomer / LDPE/EMMA (Resin A / Resin F / Resin I)	117	31.8	76	1.68	43.9	102.0	○	×
	118	34.5	85	1.42	37.2	101.4	○	
	119	41.7	100	1.03	34.0	91.8	○	
	120	41.4	100	—	34.9	88.0	×	
	121	49.4	100	—	31.6	82.0	×	

("—" in table indicates no measurement made)

Comparative Example 3 is a comparative example for Embodiment 7. With Comparative Example 3, in a foaming temperature range of 3°C, the change in density is 5 kg/m<sup>3</sup> or greater, manufacturing stability is lacking, and cell  
5 crushing was observed in the center of the cross-section of the foam obtained at a foaming temperature of 120°C or higher.

#### Comparative Example 4

10 Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 34 parts by weight of "resin A," 37 parts by weight of "resin F," and 29 parts by weight of "resin G." The  
15 density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 18.

Table 18

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
		Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Mixed Resin Type	Foaming Temperature (°C)							
Ionomer /LDPE/LDPE (Resin A / Resin F / Resin G)	116	30.6	38	1.89	39.3	100.6	○	×
	117	40.2	78	—	33.4	97.0	△	
	118	48.2	95	—	25.5	92.2	△	
	119	57.6	100	—	19.5	80.6	△	

("—" in table indicates no measurement made)

Comparative Example 4 is a comparative example for Embodiment 11. With Comparative Example 4, in a foaming temperature range of 3°C, the change in density exceeds 5 kg/m<sup>3</sup>, manufacturing stability is lacking, and portions of cell unevenness were observed in the cross-section of the foam obtained at a foaming temperature of 117°C or higher.

#### Comparative Example 5

Extruded plank-form extruded open cell foam was obtained with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 43 parts by weight of "resin A," 28.5 parts by weight of "resin F," and 28.5 parts by weight of "resin J." The density, open cell foaming ratio, average cell diameter, thickness, and width of the foam so obtained were measured, respectively, the foam cross-sectional cell uniformity and manufacturing stability were evaluated as noted above, and the results indicated, respectively, in Table 19.

Table 19

Base Resin	Foaming Conditions	Physical Properties of Foam					Cell Uniformity	Manufacturing Stability
		Density (kg/m <sup>3</sup> )	Open Cell Foaming Ratio (%)	Average Cell Diameter (mm)	Thickness (mm)	Width (mm)		
Mixed Resin Type  Ionomer /LDPE/VLDPE (Resin A / Resin F / Resin J)	117	34.7	92	1.47	39.3	98.0	○	×
	118	42.4	98	0.90	33.4	90.0	○	
	119	60.3	100	0.62	25.5	68.6	×	



Comparative Example 5 is a comparative example for Embodiment 12. With Comparative Example 5, in a foaming temperature range of 3°C, the change in density is 5 kg/m<sup>3</sup> or greater, manufacturing stability is lacking, and cell  
5 crushing was observed in the center of the cross-section of the foam obtained at a foaming temperature of 119°C or higher.

#### Comparative Example 6

10 An attempt was made to obtain rod-shaped extruded open cell foam with the same conditions as in Embodiment 1 except in that 100 parts by weight of mixed resin were made by mixing 5 parts by weight of "resin B," 67 parts by weight of "resin F," and 28 parts by weight of "resin H,"  
15 and in that the die was made 4mm  $\phi$  rod die, but no foam was obtained.

Below, the compressive strengths of the foams obtained in Embodiments 6 to 9 and Comparative Example 3 are given in Table 20, and the defection set by constant compression  
20 and defection set by repeated compressions of the foams obtained in Embodiments 6 to 10 and Comparative Example 3 are given in Tables 21 and 22, respectively. The methods

of testing for compressive strength and permanent compressive strain were as described below.

Compressive strength:

Static compression tests were performed in accordance with JIS Z0234 (1976) Method A. The dimensions of the test pieces were made 50 mm longitudinally x 50 mm across x the thickness of the foam and the load speed was made 10 mm/minute. After compressing the test piece to 80% of its thickness, the compression was released at the same speed as the load speed, and measurement was concluded at the point in time where the compressive stress became 0 Pa, to yield a stress-strain curve. The loads at the time of 5% compression and at the time of 25% compression, respectively, were read from the curve obtained, and the 5% compressive strength and 25% compressive strength were calculated therefrom.

Deflection set by constant compression:

Except in that the conditions of the test atmosphere were made 23°C temperature and 50% relative humidity, deflection set by constant compression tests were performed according to JIS K6401 (1980). The dimensions of the test pieces were made 50 mm longitudinally x 50 mm across x the thickness of the foam. The test piece was compressed to

50% and left standing in that condition for 22 hours; after which the compression was released. The thickness of the test piece was then measured, 30 minutes later and 24 hours later, respectively, and the percentage of defection set by constant compression was calculated.

Defection set by repeated compressions:

Except in that the conditions of the test atmosphere were made 23°C temperature and 50% relative humidity, defection set by repeated compressions tests were performed according to JIS K6401 (1980). The dimensions of the test pieces were made 50 mm longitudinally × 50 mm across × the thickness of the foam. The test piece was subjected to 80,000 continuously repeated compressions to 50% of the thickness thereof, at a speed of 60 revolutions/minute. Then the thickness of the test piece was measured, 30 minutes and 24 hours after the compression was released, respectively, and the percentage of defection set by repeated compressions was calculated therefrom.

Table 20

	5% Compressive Strength (kPa)	25% Compressive Strength (kPa)
Embodiment 6	5.16	9.41
Embodiment 7	6.09	10.36
Embodiment 8	4.32	8.21
Embodiment 9	5.91	10.37
Comparative Example 3	4.45	7.66

5

Table 21

	Percentage of defection set by constant compression After 30 Minutes(%)	Percentage of defection set by constant compression After 24 Hours(%)
Embodiment 6	6.8	2.0
Embodiment 7	7.4	2.2
Embodiment 8	4.4	2.3
Embodiment 9	6.1	1.8
Embodiment 10	4.9	1.1
Comparative Example 3	3.4	1.0

Table 22

	Percentage of defection set by repeated compressions After 30 Minutes(%)	Percentage of defection set by repeated compressions After 24 Hours(%)
Embodiment 6	10.7	3.8
Embodiment 7	10.9	4.5
Embodiment 8	9.0	3.1
Embodiment 9	8.3	2.6
Embodiment 10	7.8	2.4
Comparative Example 3	5.4	2.8

5

INDUSTRIAL APPLICABILITY

The extruded polyolefin resin foam of the present invention exhibits a high expansion ratio, uniform cell diameter, and outstanding mechanical properties, and is well suited for use as cushion material, packaging material, sound absorbing material, water absorbing material, anti-vibration material, and various types of industrial filter.

10

CLAIMS

1. An extruded polyolefin resin foam, characterized  
in that said extruded polyolefin resin foam is an extruded  
5 foam exhibiting an open cell ratio of 50% or greater, and  
that base resin thereof is principally composed of a mixed  
polymer consisting of 4.5 to 75 parts by weight of  
component A consisting of an ethylene ionomer resin, 0.5 to  
30 parts by weight of component B consisting of a  
10 polyolefin resin having a melting point exceeding 120°C,  
and 20 to 95 parts by weight of component C consisting of  
one or two or more polymers selected from a group of  
ethylene-propylene rubbers, styrene elastomers, and  
polyethylene resins having melting points of 120°C or lower  
15 (where component A + component B + component C = 100 parts  
by weight).

2. The extruded polyolefin resin foam according to  
claim 1, characterized in that said component B consisting  
of a polyolefin resin having a melting point exceeding  
20 120°C is one type or a mixed resin of two or more types  
selected from among polypropylene resin, linear low-density  
polyethylenes, and polyethylene resins having a density of  
940 kg/m<sup>3</sup> or greater.

3. The extruded polyolefin resin foam according to claim 1, characterized in that said polyethylene resin having a melting point of 120°C or lower in said component C is one type or a mixed resin of two or more types  
5 selected from among low-density polyethylenes, ethylene- $\alpha$  or  $\beta$  unsaturated carboxylic acid copolymers (but excluding ionomers), and ethylene-vinyl acetate copolymers.

4. The extruded polyolefin resin foam according to claim 1, characterized in that 0.1 to 15 parts by weight of  
10 an anti-shrinking agent are added to 100 parts by weight of said base resin.

5. The extruded polyolefin resin foam according to claim 1 or claim 4, characterized in that said extruded foam has a density of 15 to 200 kg/m<sup>3</sup> and a thickness of  
15 0.5 to 200 mm.

6. The extruded polyolefin resin foam according to claim 1 or claim 4, characterized in that said extruded foam is sheet-form foam or plank-form foam.

7. The extruded polyolefin resin foam according to  
20 claim 1 or claim 4, characterized in that said extruded foam is rod-shaped foam having a density of 15 to 100 kg/m<sup>3</sup>, and area of vertical cross-section thereof orthogonal to direction of extrusion being 0.7 cm<sup>2</sup> or greater.